

the examination series

Second edition

examination **INTENSIVE CARE MEDICINE**

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**CHURCHILL
LIVINGSTONE**



Introduction to the DVD content

In this edition of *Examination Intensive Care Medicine* we have created a DVD that complements the book. The reason for this is two fold. Firstly, with the growth of intensive care as a specialty and our desire to add to the content of the intensive care medicine component of the 2006 *Examination Intensive Care and Anaesthesia* publication, there was need for greater storage capacity, without necessitating the release of multiple volumes. Secondly, the format allows us to engage on a more interactive, portable and user friendly level. The topics represent the core areas that routinely appear in Critical Care specialist examinations and as much as possible, are in line with CoBaTRICE¹, the UK DICM², European EDIC³ and the Australian and New Zealand CICM⁴ guidelines and objectives of training.

The content of the DVD is fully indexed and navigable by clicking on the section or topic of interest. It is divided into the following five sections.

- Chapter supplements
- Recall cases
- Pharmacology quiz
- Case scenario flow diagrams
- Useful resources

The first section continues with material that supplements chapters 4 to 6, 9 and 10. It contains a more extensive catalogue of commonly encountered ICU data, equipment, procedures and literature. A pharmacology section is provided in quiz format.

The second section concentrates on active data interpretation, as encountered in the written and viva components of the FCICM, EDIC and DICM examinations. Common patterns and how to extract them are highlighted, with answers and explanations provided. The specific abnormalities that are used to draw the appropriate conclusions are explicitly indicated. It is thereby hoped to assist candidates to develop the ability to think critically, rapidly identify useful patterns and practice the application of what has been learned. In doing so, you should also be better able to adapt to and deal effectively with situations which you may not have specifically studied or encountered before.

Additionally, specific effort has been made to use the language of the exam in both the questions and the answers, in order to familiarise candidates with it and to encourage the use of focussed, efficient answers.

The individual topics covered in this recall case section can be accessed by sub-section or, for a bit more of a challenge, in completely random order. They are also fully indexed, in case you want to revise a specific issue. It is recognised that most hospital laboratories will have their own reference ranges for various assays and that a similar situation exists for some monitors. It is also recognised that Australian measurement units may differ from European units; e.g. mmHg versus kPa. So, a set of common reference ranges has been supplied for use during the Recall Cases. It is also recommended that you try to memorise the frequently recurring ranges, even though they are often provided in the exam, as this speeds up your data processing and can create a bit of extra time for time-hungry questions.

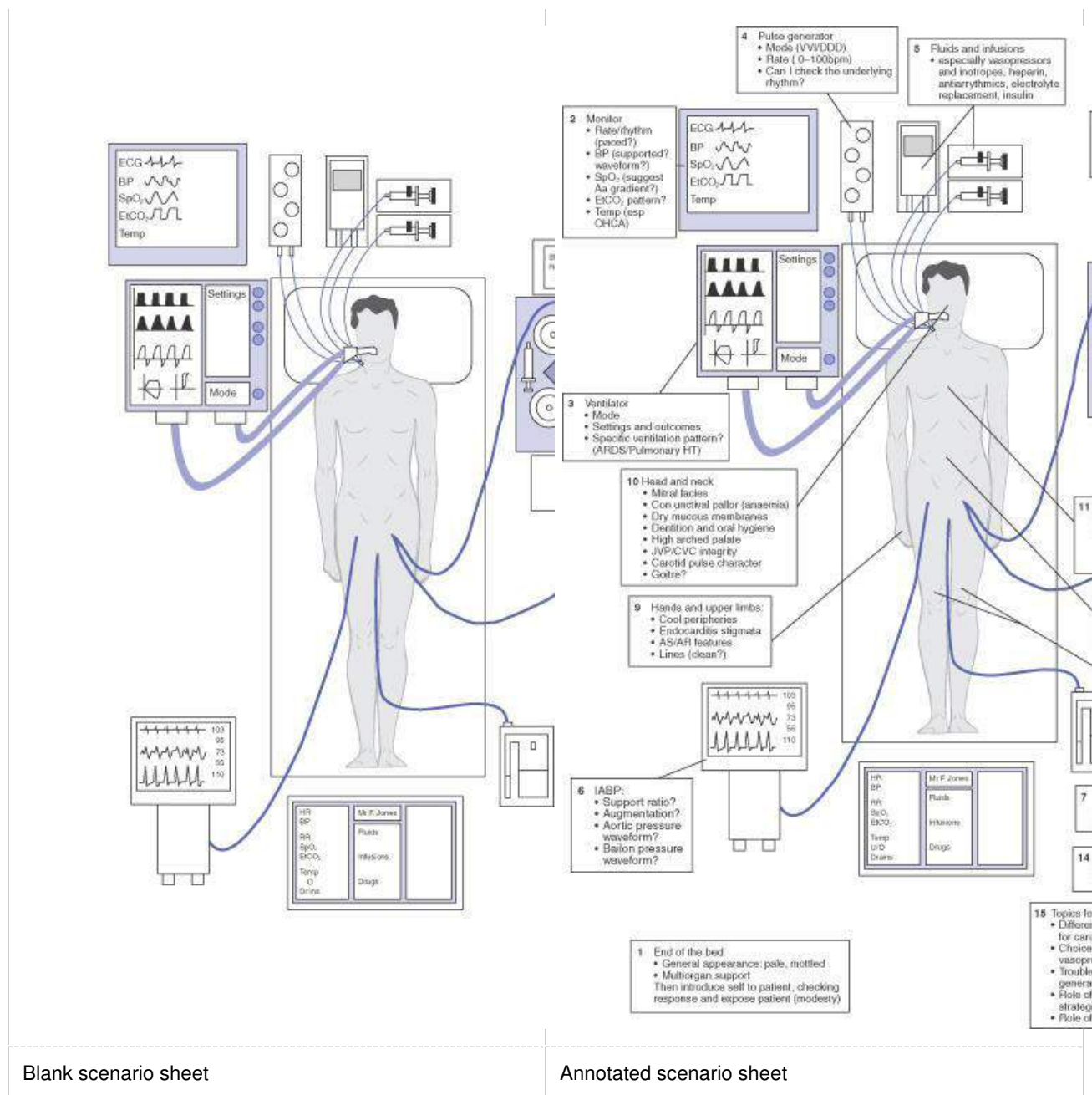
Both adult and paediatric data are presented. The key areas presented in this section are:

- **1. Laboratory**
 - Biochemistry
 - Haematology
 - Microbiology

- Endocrinology
- **2. Imaging**
- Plain films
- Computed tomography (CT)
- Magnetic resonance imaging (MRI)
- ECHO cardiography
- Other modalities (e.g. FAST)
- **3. Electrocardiographs (ECGs)**
- **4. Monitoring data**
- Non-invasive (e.g. SpO2, EtCO2)
- Invasive (e.g. PAC, PiCCO, FloTrac, CVP, ICP)
- Ventilator waveforms and capnography
- Transcranial doppler (TCD)
- Electroencephalographs (EEGs) and Bispectral index (BiS) monitors
- SSEPs and nerve conduction studies
- **5. Clinical examination patterns and spot diagnoses**

In order to make the rote learning of pharmacology facts more engaging, we have created a Pharmacology quiz for the most commonly used agents in intensive care medicine, wherein you try to work out what drug is from a series of clues.

The DVD also contains a set of scenario diagrams. These are intended to assist you with preparing for and rehearsing your approach to the clinical cases that you will encounter in your exam, such as those that are presented in Chapter 8 - Clinical cases. Each of the diagrams can be printed out as often as you need and can be used to write your own notes as you structure your strategy for tackling these and other cases. You can also leave them blank and use them to test yourself and your colleagues; particularly if you have difficulty in getting access to some of these patient types.



Finally, in preparing for a specialist exam, it is often helpful to have a list of trusted resources for finding the answers to issues that may not be covered in detail in textbooks, or where a conflict of opinion exists. So, in the final section, we have included a list of resources that we have found, and continue to find, helpful in teasing out these thorny aspects of intensive care.

We hope that you will find this DVD useful as you explore different units during your training and exam practice and that it continues to be a useful resource as you move into your specialist career.

Good luck.

EQUIPMENT

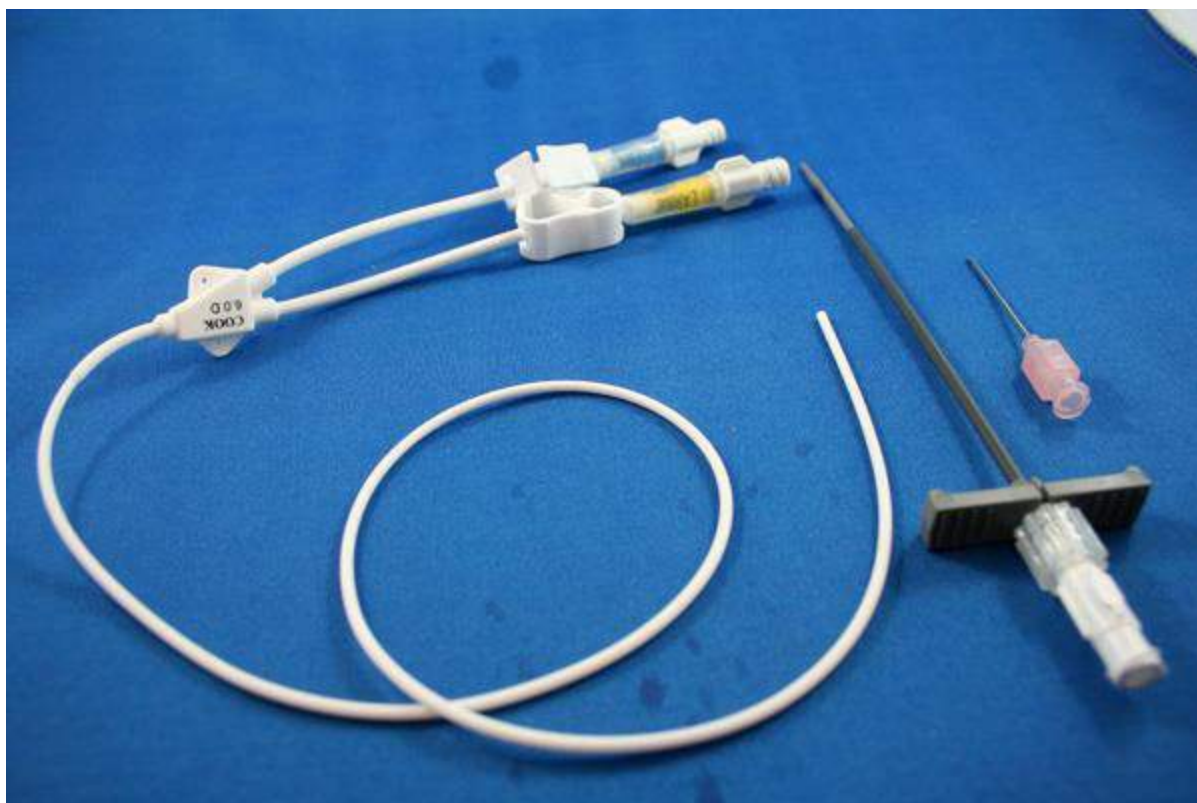
Cardiovascular - Intravenous equipment



Intravenous cannulae

1. Item name	Peripheral intravenous cannulae
2. Uses	Provides means to infuse fluid/blood. Allows blood sampling and drug administration.
3. Description	<p>A variety of devices are used with different lengths and diameters. Term cannula is used for those 7 cm or less in length.</p> <p>Cannulas commonly used are 14–24 Gauge.</p> <p>A standard cannula consists of a plastic cannula (PTFE or similar material) that is mounted on a smaller-diameter metal needle, the bevel of which protrudes from the cannula. The other end of the needle is attached to a flashback chamber that fills with blood when the vein is successfully cannulated. All cannulae have a standard Luer-lock fitting for attaching a giving set so fluids/drugs can be administered directly into the vein.</p> <p>Often the cannulae have safety features that allow the needle to be retracted inside the</p>

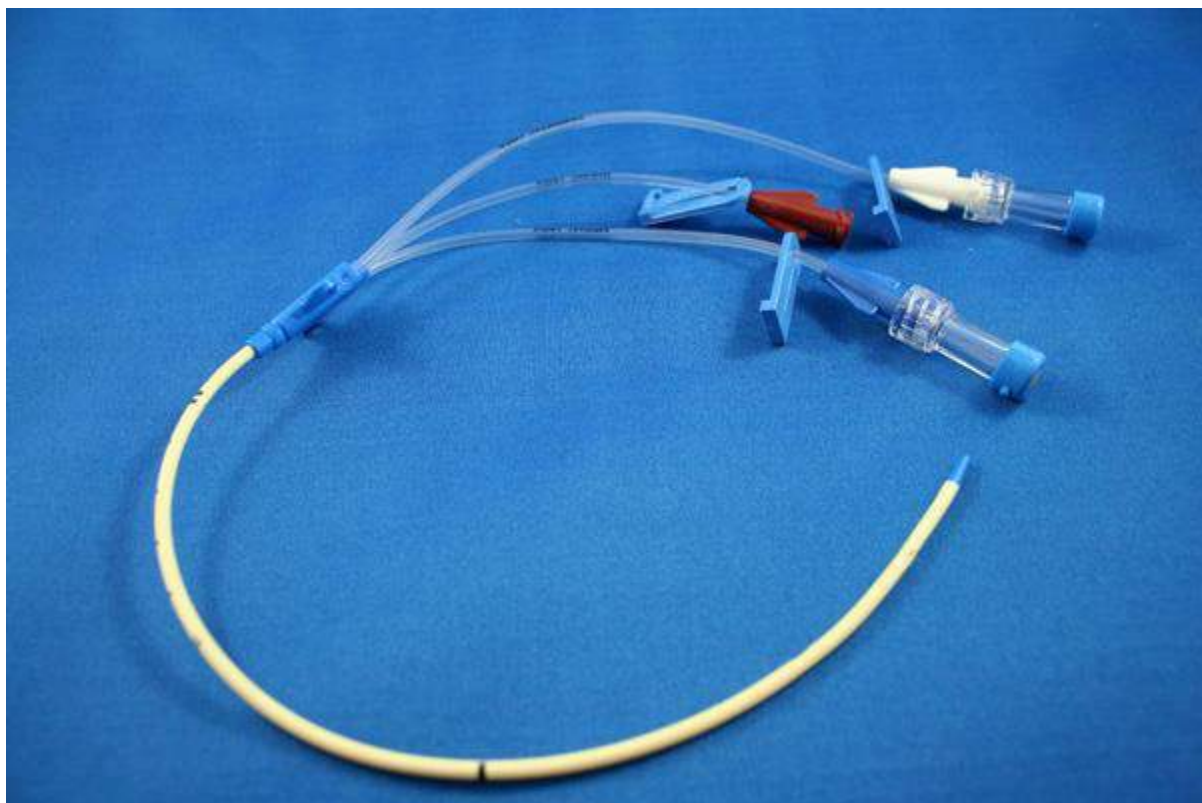
	cannula and be disposed of in one piece.
4. Method of insertion and/or use	The superficial veins of the upper limbs are generally preferred. The veins are dilated by use of a tourniquet and the vein immobilised. The cannula is held at about 15° to the skin and the vein punctured, the cannula is then advanced and the needle pulled back. Once the cannula is inserted as far as the hub, the needle is removed and disposed of safely.
5. Potential complications	<p>Failed cannulation</p> <p>Haematomas/damage to underlying structures</p> <p>Extravasation of fluids/drugs</p> <p>Thrombophlebitis</p> <p>Insertion site infection</p> <p>Septicaemia</p> <p>Inadvertent arterial</p>
6. Other information	<p>Important associated concepts:</p> <p>Flow is determined by size and diameter of the cannula (see gas cylinders and Hagen-Poiseuille Equation). For resuscitation short, wide-bore cannulae provide the most rapid infusion rate.</p> <p>Gauge and French sometimes cause confusion:</p> <p>Gauge is used to describe <i>needles</i> – larger Gauge corresponds to smaller needle diameters</p> <p>French catheter scale used to describe <i>catheters</i> – larger French size corresponds to larger catheter diameters (1Fr = 0.33 mm)</p>



PICC line

1. Item name	Peripherally inserted central catheter (PICC)
2. Uses	Fluid infusion and drug infusions, especially vasoactive drugs and long term antibiotics
3. Description	The catheters come in various diameters, with either single or double lumens. They can be antibiotic impregnated to allow long term use
4. Method of insertion and/or use	The antecubital fossa is commonly used with the basilic vein medially being the best choice, as in over 60% of cases the

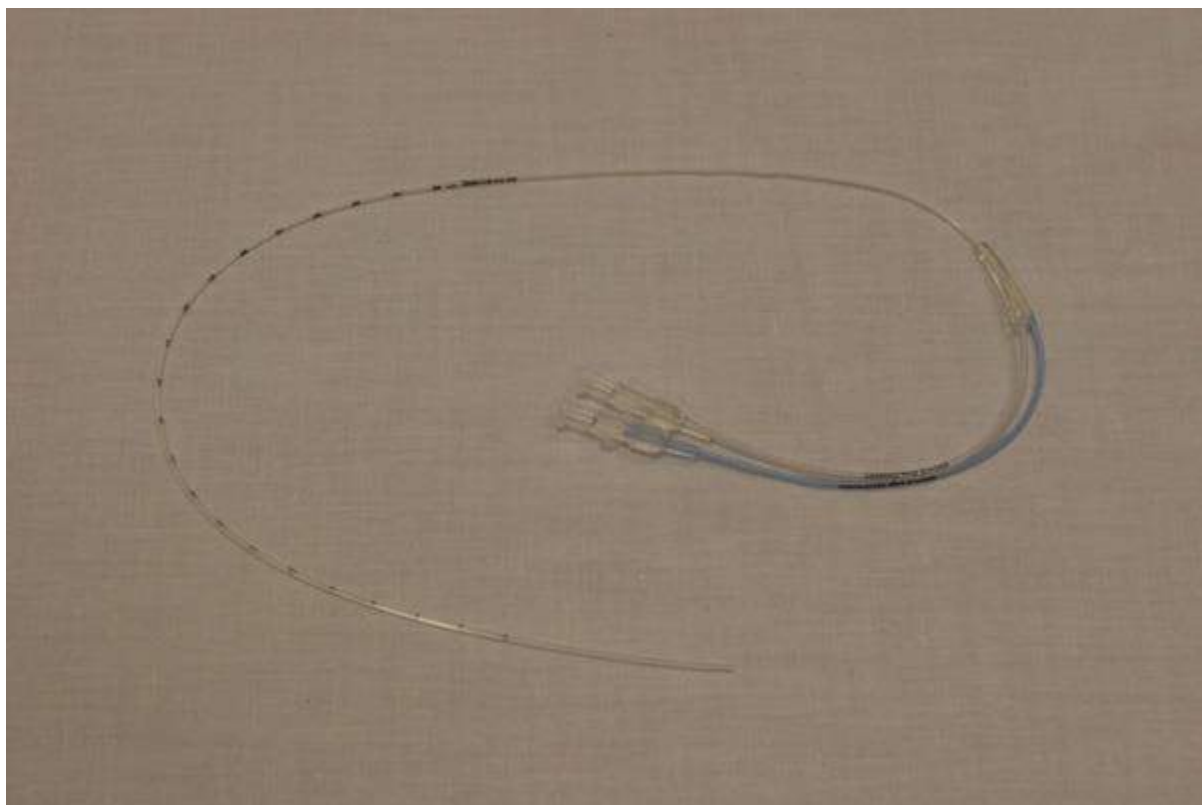
	<p>catheter can be inserted all the way into the central veins of the chest. The use of ultrasound to guide insertion has increased the number of veins available for cannulation. A Seldinger technique is variably used, using a small diameter needle to puncture the vein followed by a wire and then some form of dilator through which the catheter can be threaded. The distance to be inserted is pre-measured using a tape measure. Other kits require a large cannula to be inserted that the catheter is fed up after removing the needle. Finally, the cannula sheath is peeled off. Some come with a securing device (e.g. Stat Lock™).</p>
5. Potential complications	<p>Vascular injury/haematoma</p> <p>Air embolism</p> <p>Infection (increases with number of lumens)</p> <p>Deep vein thrombosis</p> <p>Pericardial tamponade</p>
6. Other information	<p>Some catheters are designed to tolerate high pressure injection of contrast for imaging procedures.</p>



Triple lumen central venous line

1. Item name	Central Venous Line
2. Uses	<p>Used if peripheral vein cannulation has failed, or if access to the central veins or right side of the heart is needed.</p> <p>Allows fluids and drugs (including vasoactives and irritant substances) to be infused.</p> <p>Enables measurement of the central venous pressure and waveform analysis</p> <p>Sheaths in a central vein can enable subsequent placement of a pulmonary artery catheter or insertion of pacing wires.</p>
3. Description	<p>Catheter with various numbers of non-communicating lumens from 1 to 5, with 3 being the most common in. Lumens are commonly designated as distal, proximal and middle lumens. The length of the catheters ranges from 15–50 cm and the diameter from 7–10 F for use in adults. Some of the lines are impregnated with antibiotics, silver-containing substance and/or chlorhexidine to reduce infection risk.</p>
4. Method of insertion and/or use	<p>Catheters are inserted into a pre-assigned central vein using a Seldinger technique. Major sites used are internal (or external) jugular, subclavian and femoral veins. Position is confirmed by aspiration of venous blood, when a central venous pressure waveform is transduced from the distal lumen, and CXR showing appropriate position.</p>

<p>5. Potential complications</p>	<p>Arterial puncture, pneumothorax, injury to nerves</p> <p>Infection</p> <p>Venous thrombosis</p> <p>Air embolism</p>
<p>6. Other information</p>	<p>Government initiatives targeting central line infection rates have standardised insertion protocols. Using ultrasound to assist identification and entry into the chosen vein may assist those learning the technique and reduce complications.</p>



Double lumen umbilical venous catheter

1. Item name	Umbilical venous catheter
2. Uses	Used in infants up to 2 weeks old if shocked or with cardiopulmonary failure.
3. Description	Various catheters – 5 or 8 Fr; single or double lumen.
4. Method of insertion and/or use	<p>Sterile technique. Scalpel used to trim the umbilical cord to 1–2 cm above the skin surface.</p> <p>The vessels are identified – umbilical vein is a single, thin-walled large diameter lesion usually located at 12 o'clock as opposed to the arteries, which are smaller, thicker and paired.</p> <p>Forceps are inserted into the end of the vein to dilate it and the catheter is then advanced towards the liver by 4–5 cm or until blood returns. Secured in various ways (e.g. umbilical cord tape).</p>
5. Potential complications	<p>Haemorrhage from vessel perforation</p> <p>Infection</p> <p>Hepatic vein thrombosis</p>
6. Other information	Temporary device only. Should be removed after intravenous definitive access is secured.



Cook intraosseous needle

1. Item name	Intra-osseous needle
2. Uses	<p>Failure to secure intravenous access in an emergency.</p> <p>More commonly used in young children when intravenous access can be very difficult. Drugs injected into the bone marrow are absorbed almost immediately into the systemic circulation via medullary venous channels. Any drugs that are given intravenously can be given through an intraosseous needle. In paediatric resuscitation, fluids given at rates of 10 mL/min can contribute to restoring the intravascular volume, however in adults its utility is limited to drug administration.</p> <p>Blood can also be taken for routine analysis.</p>
3. Description	<p>15–18 G stylet mounted on a hollow rigid needle. Traditional manual needles have a rounded handle that fits into the palm of the hand to allow insertion</p>

that is then removed once the needle is in situ. Drill kits are increasingly used where the stylet and needle screw into the drill for insertion (e.g. EZ IO™).

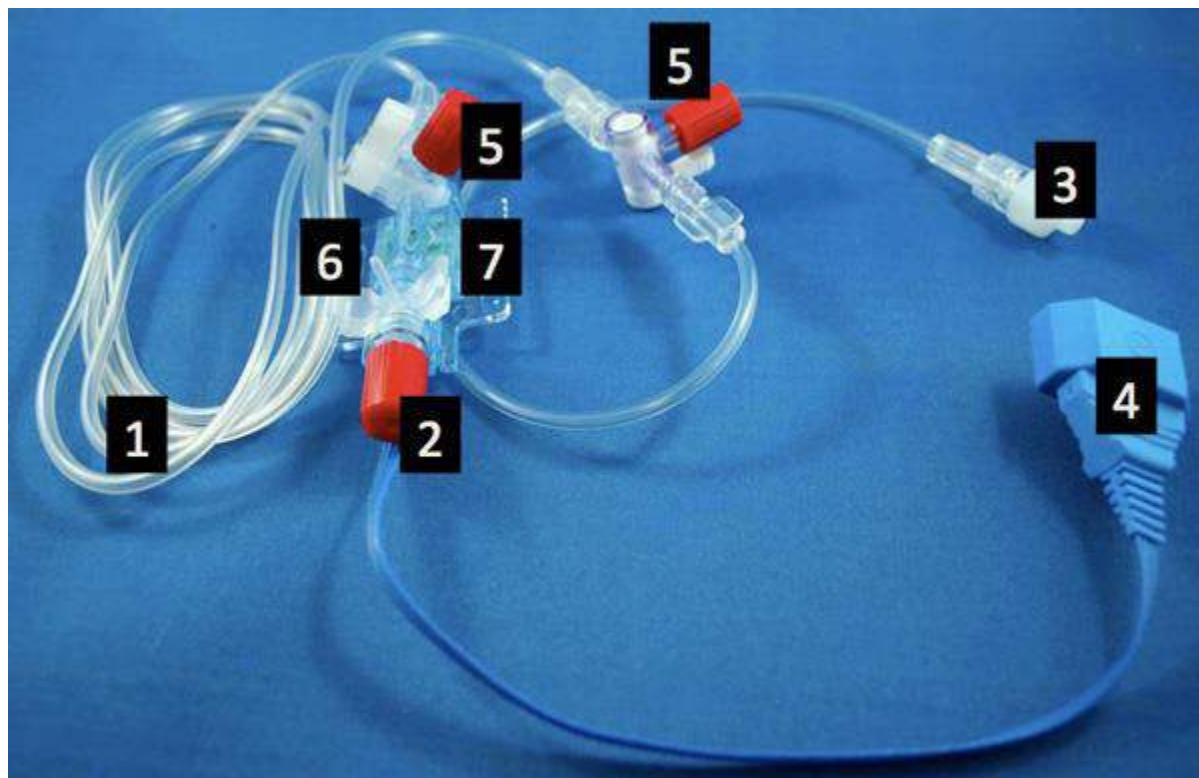
4. Method of insertion and/or use

The proximal tibia is the preferred anatomical site, with the entry site a few centimetres below the tibial tuberosity. The needle is held in the palm of the hand and is directed caudally away from the upper tibial epiphysis in the line of the shaft. A firm pressure combined with a twisting action is used to traverse the bone. Position is confirmed by experiencing a give as the marrow is reached, the needle flushes easily and bone marrow is aspirated and the needle stands tall without support.

5. Potential complications	Bleeding Dislodgement and extravasation Infection – cellulitis, osteomyelitis, septicaemia Fracture
6. Other information	Only provides a bridge to definitive intravenous access.

Cardiovascular - Cardiovascular monitoring devices

Monitoring Devices



Pressure transducer photo

Figure legend:

1. Low-compliance tubing
2. Connection to line attached to pressure bag
3. Connection to blood-filled tube (e.g. arterial line)
4. Signal cable for connection to monitor cable

5. Tap-controlled sampling port (also to enable zeroing)
6. Rapid flush device (pull lever)
7. Transducer membrane

1. Item name	Pressure transducer system
2. Uses	Allows invasive pressure monitoring in various compartments of the cardiovascular system, including arterial, central venous and right-sided heart pressure. Also used for measuring pressures in other body cavities, i.e. intra-abdominal, intracranial.
3. Description	The components are the in situ catheter (i.e. arterial line), coupled with low-compliance extension tubing, the pressure transducer and the amplifier/monitor. When used for cardiovascular pressures, the fluid-filled components are connected to an automatic flush device and inflatable pressure bag.
4. Method of insertion and/or use	The external end of the catheter is connected to fluid-filled connecting tubing. This fluid transmits the pressure changes at the catheter tip to the pressure

transducer (an electromechanical device that converts pressure into an electrical signal). Generally pretested, precalibrated and presterilised disposable transducers are used. All have a pressure-sensitive diaphragm, enclosed by a fluid-filled dome and as the patient's pressure pulsations physically strike the diaphragm, this mechanical movement is converted into an electrical signal (via a Wheatstone bridge – a set-up of 4 resistors and a galvanometer that increase the size of the electrical signal generated), which is processed and displayed by the monitor.

The system must be given a zero reference point to establish a standard neutral level for all measurements. This eliminates the effects of atmospheric and hydrostatic pressures. The transducer is exposed to the atmosphere. The monitor should read zero. The system is then levelled to a reference point (e.g. the phlebostatic axis for CVP).

Depending on the

	monitor used, some calibration may be required.
5. Potential complications	<p>Those related to catheter insertion.</p> <p>Inaccuracy related to system set-up.</p> <p>Decision-making based entirely on monitoring information rather than adding this to clinical examination.</p> <p>Bleeding if system disconnected.</p> <p>Accidental drug administration.</p>
6. Other information	<p>Important associated concepts:</p> <p>Once the system oscillates from the pulse pressure waveform, further oscillations occur due to the resonant frequency of the system (F_0), causing distortion of the recorded waveform.</p> <p>The pressure waveform is a graphical representation of a complex wave, consisting of the summation of mechanical pressure signals at different frequencies. The summation of between 6 and 10</p>

harmonics are required to create an accurate arterial pressure waveform.

The longer the fluid-filled tubing, the lower the natural frequency of the monitoring

system and the greater the chance of signal distortion. 30 Hz is thought to be the

minimum desirable natural frequency of an optimally damped monitoring system

(1 Hz = cycle/second).

Fundamental frequency = square of the pulse rate.

Fourier analysis is the process used to sum the series of waves, which are harmonics of the fundamental frequency.

Damping is the absorption of oscillatory energy by frictional forces

and hence reduces artefacts that can distort the pressure waveform.

If the damping coefficient (DC) = 1, only the MAP is recorded as there is no resonance at all. Optimal damping (DC = 0.6–0.7) is when all oscillatory forces (of the monitoring system) are diminished such that only the pulse pressure waveform is recorded.

Damping is increased by air bubbles, using soft, overly compliant tubing (e.g. as a system length extension), tube narrowings (e.g. clots, partial kinking) and deflated pressure bag, and damping is decreased by using excessive tubing lengths.

Static calibration of a system involves transducer zeroing to a reference point and setting of an

appropriate gain for the displayed waveform.

Dynamic calibration is now generally relevant to manufacturers of devices and refers to the use of systems with optimal damping and appropriate resonance frequency for the system. A rough visual assessment may be made with a fast-flush test (e.g. for an arterial line, after a rapid flush of fluid from the pressure bag, an obvious square wave will be seen then one undershoot below the baseline, then a small overshoot above the baseline if the system has acceptable damping. An overdamped system will have no or minimal oscillations and excessive oscillations are seen in an underdamped one.



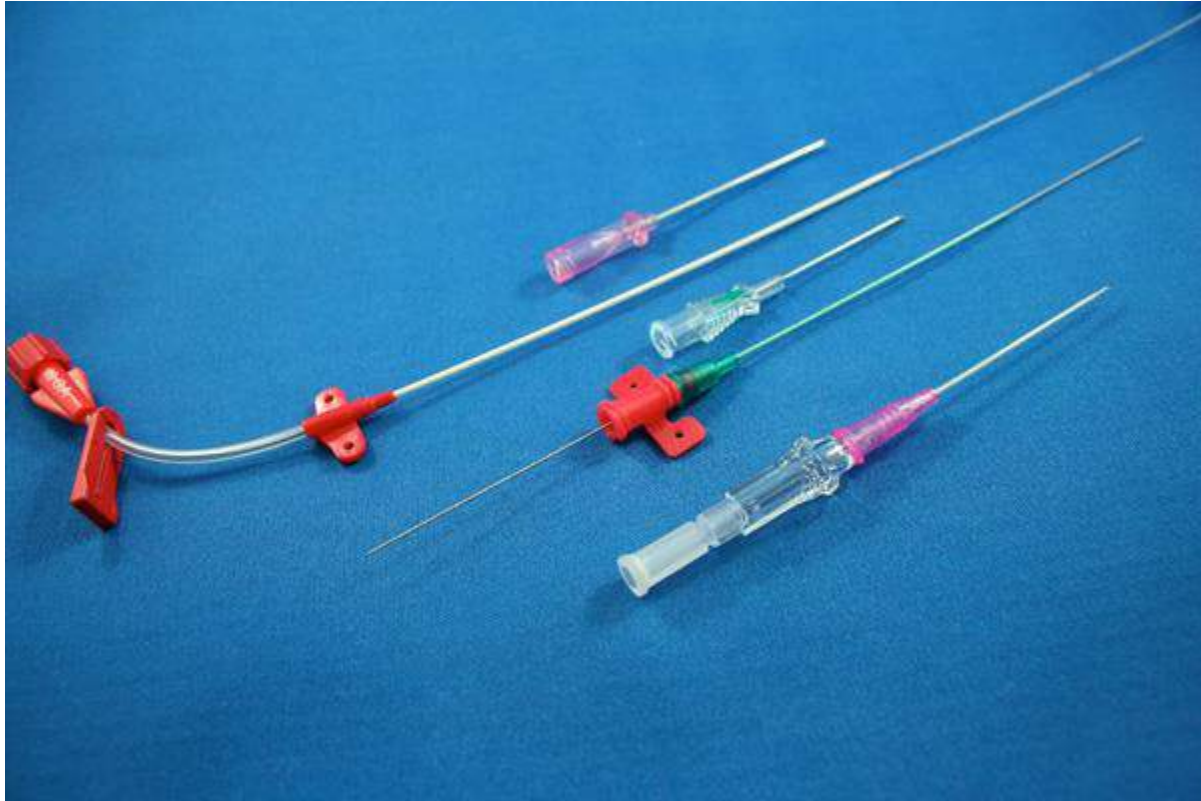
Riva-Rocci blood pressure cuffs

1. Item name	Non-invasive blood pressure devices
2. Uses	To measure blood pressure using non-invasive measurement techniques
3. Description	<p>All methods are based on the use of a pneumatic cuff that is placed on the upper arm and gradually deflated with changes in the flow of blood under the cuff used to measure the systolic and diastolic blood pressures.</p> <p>Requires an inflatable cuff (termed Riva Rocci cuff) linked to a manometer.</p> <p>Common devices:</p> <p>Mercury sphygmomanometer – used with a stethoscope to listen to characteristic Korotkoff sounds or by palpating a pulse located distally in the limb with the cuff applied (e.g. radial artery at the wrist)</p> <p>Anaeroid manometers</p> <p>Oscillometric manometers</p>
4. Method of	The cuff is inflated to occlude all circulation to the limb, the cuff is then gradually

insertion and/or use	<p>deflated and the point at which arterial flow returns is the systolic blood pressure. As the cuff pressure is further reduced the character of the arterial flow changes from turbulent to uniform at the diastolic blood pressure. The automated machines use an electrical pump to inflate the cuff and then induce a controlled deflation.</p>
5. Potential complications	<p>Inaccurate readings if cuff is poorly fitted – cuff width should be about 40% of the mid-circumference of the limb.</p> <p>Auscultation may be impossible in environments with high ambient noise (e.g. transport vehicles) and is operator dependant.</p> <p>Can have problems determining a correct reading when the pulse is irregular (e.g. arrhythmias with variable cardiac output such as AF, pulsus paradoxus, pulsus alternans, loss of transmitted pulse if severe atherosclerosis).</p> <p>Oscillometric technique can be inaccurate if the patient is moving around.</p> <p>Repeated measurements can cause skin bruising, oedema and even ulceration.</p> <p>Pressure from cuffs should be avoided in ischaemic limbs or when there is impaired venous or lymphatic drainage (e.g. after axillary node dissection).</p>
6. Other information	<p>Important associated concepts:</p> <p>Blood flows through the arteries under force and blood pressure is a measure of this; it combines the pressure generated as the heart pumps and the resistance to blood flow through the arteries. Pressure estimate relies on changes in blood flow under a cuff as it is compressed and released.</p> <p>Manometers = devices that measure pressure.</p> <p>Mercury manometer = oldest type of manometer; the height of a column of mercury is used to reflect blood pressure by correlating readings at the same time of auscultated or palpated pulse changes are recognised by the operator.</p> <p>Anaeroid ('without fluid') manometer = a metallic sensor changes shape or moves in response to pressure. Pressure sensing element can vary such as a diaphragm or membrane, bellows or Bourdon tube (a flattened tube that fills out to become more tubular when pressure is applied); as the pressure is applied a needle moves along a calibrated pressure gauge indicating the pressure reading.</p> <p>Oscillometric manometer = a micro-processor-controlled pressure transducer detects arterial wall movements and then calculates systolic, mean and diastolic pressure and heart rate.</p> <p>Measurement of mean arterial pressure (MAP) is the most reliable measure of blood</p>

pressure, as it is least dependent on measurement site, least affected by measurement damping and it determines actual tissue blood flow.

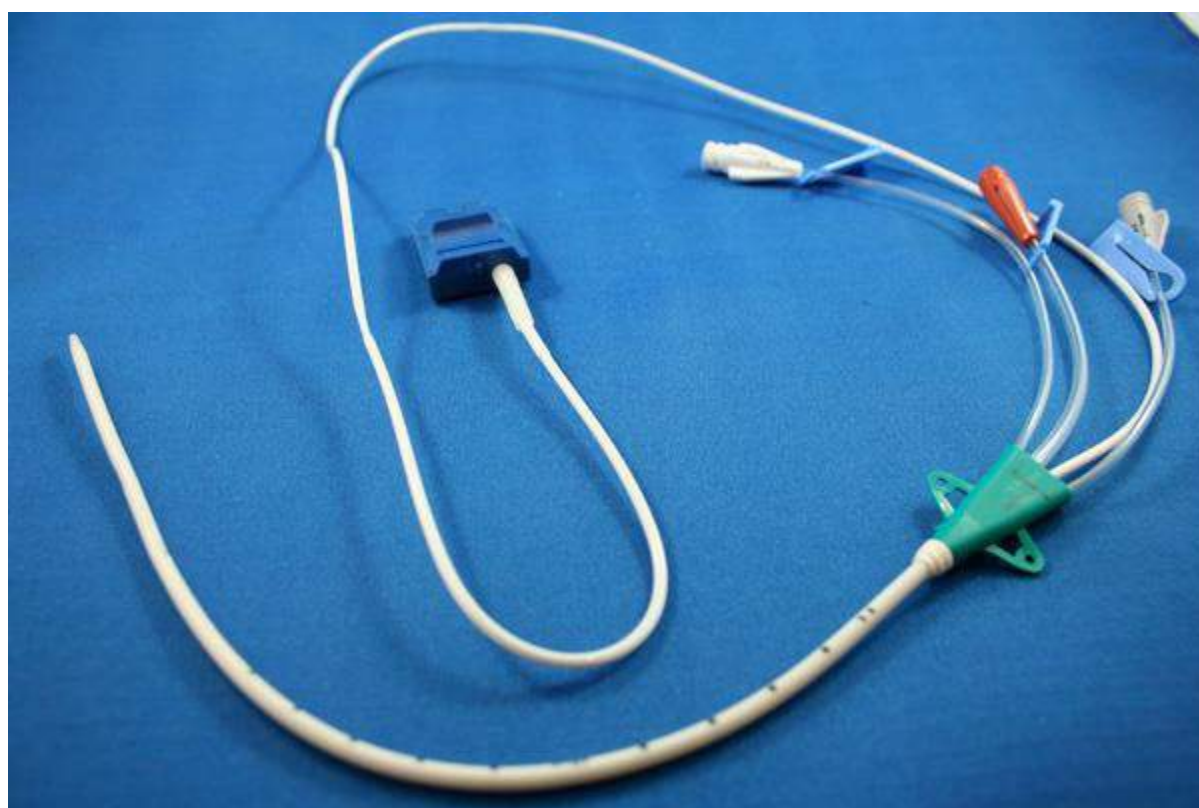
$$\text{MAP} = \text{DBP} + \frac{\text{pulse pressure}}{3}$$



Arterial lines

1. Item name	Arterial line
2. Uses	Allows arterial cannulation with continuous blood pressure monitoring, beat-to-beat waveform display and repeated blood sampling including blood gases.
3. Description	<p>Long 20G 48 mm Insyte™ Cannula (for adult radial artery) or purpose-specific kits, using a Seldinger technique.</p> <p>Cannula is then connected to a pressure transducing system.</p>
4. Method of insertion and/or use	Most common insertion sites are the radial or femoral artery (sometimes the brachial or dorsalis pedis artery). Aseptic technique with direct cannulation of the artery

5. Potential complications	<p>Vascular injury/bleeding</p> <p>Ischaemic digits or limb (reduced flow or thromboembolic events)</p> <p>Injury to other structures such as nerves</p> <p>Infection</p>
6. Other information	Standard method of measuring blood pressure in ICU



PreSep™ catheter

1. Item name	Continuous central venous oxygenation monitor
2. Uses	Central venous oxygen saturation (ScvO ₂) reflects the balance between oxygen delivery and consumption. Normally oxygen extraction is about 25–30% and ScvO ₂ >65% reflects optimal

	<p>balance. Current sepsis guidelines recommend instituting goal directed therapy when the ScvO₂ <70%. The ScvO₂ may also have a role in the management of postoperative patients.</p>
3. Description	<p>PreSep™ central venous oximetry catheter, allows continuous measurement of CVP and ScvO₂ through the Vigileo™ monitor. The line combines a standard central line with 3 lumens for use, with specialised fibreoptics on the tip that measure the venous oxygenation.</p> <p>CeVox™ another device that can provide continuous venous oximetry. It is a fibreoptic line that is fed down one lumen of a pre-existing central line and then connected to a PiCCO™ monitor.</p>
4. Method of insertion and/or use	<p>PreSep™ is inserted like any other central line into either the internal jugular or subclavian veins. It is connected to a Vigileo™ monitor and calibrated using a central gas taken from the line and knowledge of the patients' age, weight, height and haemoglobin.</p> <p>CeVox™ line is threaded down the distal lumen of the central line and then secured. Calibration involves a central blood gas and patient demographics.</p>
5. Potential complications	<p>PreSep™ – as per any central venous access device</p> <p>CeVox™ – can block lumen completely and be difficult to insert depending on age of central line. Prone to drift.</p> <p>Potential misinterpretation of the values if devices are not calibrated or if catheters are not positioned properly.</p>

6. Other
information

Both devices not in common clinical use, but used by those with an interest in Early Goal Directed Therapy.

Devices that measure O₂ saturation in various locations within the circulatory tree are not new. Jugular venous bulb oximetry has been used for many years for research and in some units is a mainstay of neurosurgical ICU practice. Catheters are most commonly inserted retrogradely into the internal jugular vein. Continuous fibreoptic oximetry catheters or semicontinuous measurements using fibreoptic probes are available for this purpose.

Cardiovascular - Cardiovascular output devices

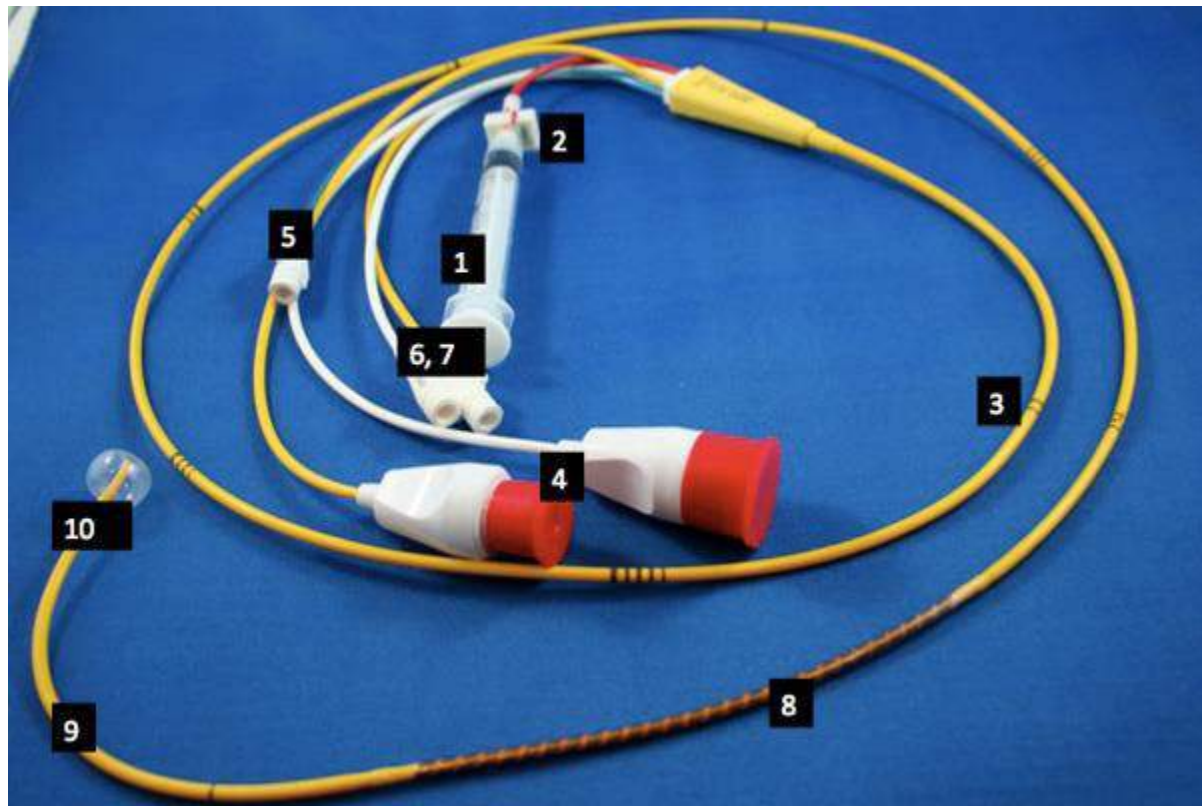


Figure legend:

Continuous cardiac output thermodilution catheter

1. Syringe (plunger withdraws only to 1.5ml)
2. Sliding locking device
3. Markings designating distance from tip (each broad mark represents 10cm)
4. Connectors to monitor (e.g. Edwards Vigilance™)
5. Lumen (proximal injectate – blue)
6. and 7. Lumens (proximal infusion – white; PA distal (for attachment to transducer) – yellow)
8. Temperature sensitive wire with thermistor bead
9. 8 French PVC yellow catheter
10. Balloon surrounding tip-containing lumen in end

1. Item name	Pulmonary artery catheter
2. Uses	Allows measurement of the pressure in the pulmonary artery, central temperature, Mixed venous saturations and Cardiac output. Some are capable of continuous cardiac output monitoring. Used to aid assessment and management of those with complex cardiac dysfunction such as myocardial infarction with cardiogenic shock and post-cardiac surgery. Also sometimes in shocked states and complex obstetric cases Therapeutic uses include provision of pacing to both the atrium and ventricles

<p>3.</p> <p>Description</p>	<p>Are available in a number of sizes for both adults and children. They range from 60-110cm in length and 4-8F in calibre. Balloon inflation volumes range from 0.5-1.5ml. The catheter is made from polyvinyl chloride that is pliable at room temperature and softens further at body temperature. The catheter is marked at 10cm increments to aid insertion. The catheters are slightly different depending on the manufacturer. All are based around the following quadruple-lumen thermodilution catheter with various additions.</p> <ol style="list-style-type: none"> 1. The distal port (pulmonary artery port) opens to a lumen that runs the length of the catheter and terminates at the catheter tip. This port measures the pulmonary artery pressures, and mixed venous gases can be drawn from it. Drugs and caustic/hyperosmolar solutions should not be infused through this lumen. 2. The balloon inflation port opens to a lumen that terminates within the balloon. 3. The proximal (right atrial (RA) port) opens to a lumen that terminates 30cms from the tip of the catheter. Therefore this opening lies within the right atrium when the tip of the catheter is in the pulmonary artery. This port can monitor RA pressures, give fluids and drugs and receive the injectate for cardiac output studies. 4. The thermistor port incorporates a temperature-sensitive wire that terminates approximately 4 to 6 cm proximal to tip of the catheter. The terminal portion of the wire, termed the thermistor bead, lies in one of the main pulmonary arteries when the catheter tip is properly positioned. Connection of the thermistor port to a CO monitor allows determination of a CO using thermodilution. <p>Other additions include:</p> <p>Catheters that offer pacing capabilities</p> <p>Those with fiberoptics allowing continuous in vivo monitoring of mixed venous oxygen saturation</p> <p>Thermodilution catheters for continuous cardiac output measurements. The catheter has a built in thermal filament that heats the surrounding blood in the right ventricle (RV) and the temperature change is detected by a thermistor located in the tip of the catheter in the pulmonary artery. This change is cross correlated with the RV thermal input to produce a thermodilution wash-out curve and the area underneath is used to get the CO. This information is used to generate graphs of CO change over time.</p>
<p>4. Method of insertion and/or use</p>	<p>The catheter is inserted (see Chapter 5 for further details) using a percutaneous Seldinger technique. A sheath is inserted as per central line insertion to provide a conduit for the PAC to pass into the pulmonary circulation. A transducer is attached to the distal lumen and with the balloon inflated allows the PAC to progress through the right heart as distinct waveforms plus known distance inserted aid certainty about position. Once the pulmonary artery is reached and wedge waveform confirmed the catheter is secured with the balloon deflated.</p>

	<p>The pulmonary artery occlusion pressure or wedge is normally related to left ventricular end-diastolic pressure or preload and may give a more accurate indication of the circulating volume. There is some concern about the use of wedge pressures due to risk of pulmonary artery rupture and generally PAC are no longer wedged routinely. Other direct measurements include pulmonary artery pressures Following thermodilution various parameters are generated that reflect haemodynamic status including CO/CI and SVR/SVRI.</p>
5. Potential complications	<p>All those associated with central line insertion</p> <p>Ventricular arrhythmias</p> <p>Pulmonary infarction/pulmonary artery rupture</p> <p>Balloon rupture/knot formation</p> <p>Infection</p> <p>Inappropriate management of the patient based on misinterpretation or misunderstanding of the data generated</p>
6. Other information	<p>Not a benign procedure. Caution in those with bleeding tendencies, hypercoagulable states, immunosuppression and those on anticoagulants.</p>



PiCCO™ catheter photo

1. Item name	Pulse contour continuous cardiac output catheter (PiCCO™)
2. Uses	Minimally invasive measurement of cardiac output (CO) and other haemodynamic parameters
3. Description	The PiCCO™ catheter is an arterial line with a thermistor on the end and is inserted into a large artery, generally the femoral but the axillary can be used. The PiCCO™ system uses pulse contour analysis to provide a continuous display of CO according to a modified version of Wesseling's algorithm combined with a transpulmonary thermodilution technique to offer complete haemodynamic monitoring.
4. Method of insertion and/or use	For the PiCCO™ system to work the patient must also have a central line in situ. The PiCCO™ is attached via a pressure transducer to the PiCCO™ monitor, which requires various patient demographics to be entered prior to calibration. The central line has an injection port on it and known volume of cold normal saline is injected once the system is stable. From the temperature difference detected a dissipation curve is generated and Stewart Hamilton equation applied to calculate CO. Other measures generated include those reflecting preload, including global end-diastolic blood volume (GEDV) and intrathoracic blood volume (ITBV). The extravascular lung water is also calculated and has been shown to be a sensitive indicator of pulmonary oedema. Other values generated include arterial blood pressure, heart rate, stroke volume, systemic vascular resistance, and cardiac function index. The manufacturer has produced decision trees to help with the use of some of these relatively new parameters and how they reflect haemodynamic status
5. Potential complications	As for any arterial line Volume/use of cold fluid in haemodynamically unstable patients.

6. Other
information

Inaccurate measurements in the presence of intracardiac shunts, aortic aneurysm, aortic stenosis, pneumonectomy, in the presence of a balloon pump and in unstable arrhythmias.

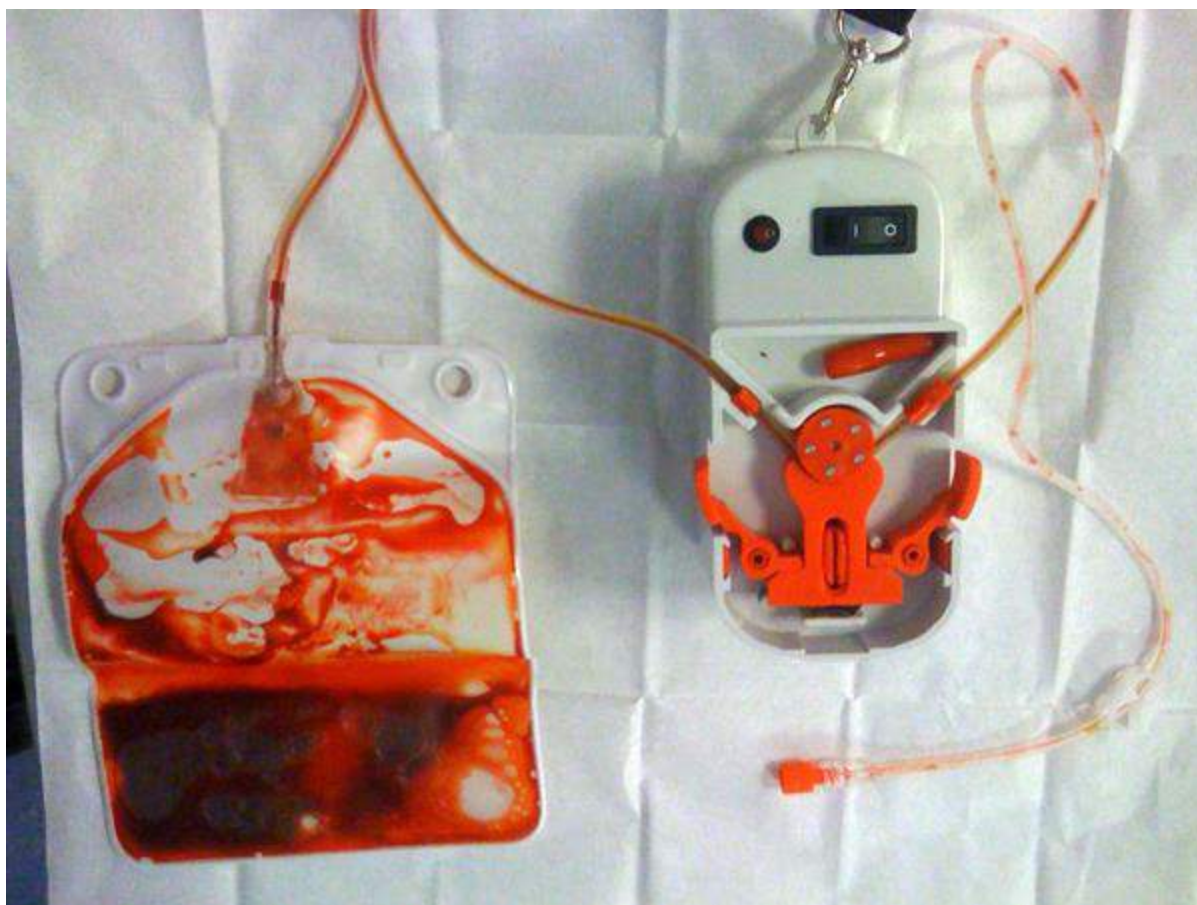
Need to calibrate in unstable patients and after changes to management occur that could affect haemodynamics.



Oesophageal doppler photo

1. Item name	Oesophageal Doppler
2. Uses	Minimally invasive measurement of cardiac output (CO) and other haemodynamic parameters
3. Description	<p>The oesophageal Doppler measures blood flow velocity in the descending aorta using a flexible ultrasound probe. This measurement is combined with the cross-sectional area of the descending aorta (obtained from nomograms based on age, weight and height), to enable calculation of stroke volume and cardiac output. The technique is based on the Doppler principle: an ultrasound beam is directed at a column of flowing blood, the sound wave is reflected when it encounters a group of moving red cells causing a Doppler shift in frequency which is proportional to the velocity of the blood flow.</p> <p>Doppler equation: $Fd = \frac{2FtVC\cos\theta}{C}$ where Ft is the transmitted Doppler frequency, V is the speed of blood flow, Cos θ is the Cosine of the blood flow to beam angle and C is the speed of sound in tissue.</p>
4. Method of	The oesophageal Doppler probe contains crystals that produce a continuous ultrasound wave of 4

insertion and/or use	<p>MHz. The probe is single use, latex-free, silicone-based and is inserted via the nasal or oral route. It is advanced and rotated in the oesophagus (typically sits at level of the 5th and 6th thoracic vertebrae where the aorta is adjacent and parallel to the oesophagus) until an appropriate aortic trace is obtained on the CardioQTM interactive monitor. The CardioQTM screen displays the waveform confirming the optimal probe position and displays the following haemodynamic parameters: cardiac output, stroke volume, corrected flow time, peak velocity and heart rate. The advantages of the oesophageal Doppler is that it is minimally invasive, offers real time measurement and requires minimal technical skill.</p>
5. Potential complications	<p>Oesophageal injury</p>
6. Other information	<p>The oesophageal Doppler probe may lose its waveform with only a slight positional change and produce dampened, inaccurate readings. It is mandatory to ensure an adequate signal prior to interpreting Doppler-derived data. Failure to reposition the probe prior to each measurement may lead to grossly erroneous cardiac output values and poor agreement with other techniques. In addition, absolute values of cardiac output may not be very accurate. Of note, the cross-sectional area of the descending aorta is a calculated value based on nomograms and is not a measured value.</p> <p>The oesophageal Doppler may be difficult to use in the awake patient and is contraindicated following oesophagectomy or oesophageal injury.</p>



LIDCO™ photo

1. Item name	LIDCO™/ PULSECO™
2. Uses	Minimally invasive measurement of cardiac output (CO) and other haemodynamic parameters
3. Description	The LiDCO™/ PULSECO™ is based on a bolus indicator dilution technique to measure cardiac output that is calibrated to the arterial waveform analysis algorithm.
4. Method of insertion and/or use	<p>Isotonic lithium chloride (150 mM) is injected (0.002-0.004 mmol/ kg) as a bolus via a central or peripheral venous route. A lithium ion-selective electrode attached to the arterial line generates a concentration-time curve. The cardiac output is calculated from the lithium dose from the area under the concentration-time curve using the equation:</p> $\text{Cardiac output} = \frac{\text{lithium dose (mmol)} \times 60}{\text{Area (1-PCV) (mmol/sec)}}$ <p>where the area is the integral of the primary curve, and PCV is packed cell volume (Hb (g/ dl)/ 34). A correction for PCV is necessary because lithium is distributed in the plasma. The</p>

	<p>voltage response of the lithium ion-sensitive electrode is to a percentage change of ion concentration, and as lithium is not normally present in the plasma, extremely small doses can be used. These doses are too small to exert pharmacological effects.</p> <p>The PulseCO[®] monitor then calculates continuous cardiac output following LiDCO calibration, by an analysis of the arterial blood pressure trace. The arterial blood pressure trace undergoes a three-step transformation (a) arterial pressure transformation into a volume-time waveform (b) derivation of nominal stroke volume and heartbeat duration (c) nominal stroke volume and calibration.</p> <p>PulseCO[®] also continuously measures arterial pressure variations. These pressure variations are measured in real time and are presented as stroke volume variation (SVV), systolic pressure variation (SPV) and pulse pressure variation (PPV). SVV is the reduction in left ventricular stroke volume associated with reduced venous return during positive pressure ventilation. PPV is defined as the maximum pulse pressure minus the minimum, divided by the average of these two pressures. SPV is the difference between the maximum and minimum systolic pressure following inspiration. SVV, PPV and SPV are a result of cyclical changes in intrathoracic pressure with positive pressure ventilation resulting in transient changes in ventricular preload and hence cardiac output. Studies have shown that these variations, in mechanically ventilated patients, are sensitive predictors of the response to volume administration and can be used as a guide for fluid therapy.</p>
5. Potential complications	As for any arterial line
6. Other information	<p>As the concentration change of lithium is used to calculate the cardiac output, LiDCO[®] cannot be used in patients receiving lithium therapy. Inaccurate measurements in the presence of certain muscle relaxants (e.g. atracurium), intracardiac shunts and unstable arrhythmias</p> <p>Need for regular re-calibration.</p>



Flo Trac System™ photo

1. Item name	Flo Trac System™
2. Uses	Minimally invasive measurement of cardiac output
3. Description	Specialised sensor attaches to a radial arterial line that needs to already be inserted. The system takes readings from the arterial line and analyses pressure information to calculate the cardiac output (CO) and other parameters derived from the CO measurement. Uses a form of pulse contour analysis with patented algorithms developed by the company.
4. Method of insertion and/or use	The Flo Trac™ is simply connected to the arterial line via a standard pressure transducer. The system requires no calibration and is connected to a Vigileo™ monitor. Parameters displayed are CO/CI, Stroke volume (SV)/SVI, Systemic vascular resistance (SVR)/SVRI, and Stroke volume variation (SVV). The SVV is used in ventilated patients and

	<p>shows variations in arterial pulsations caused by volume changes during positive pressure ventilation. A value >15% may indicate hypovolaemia.</p>
5. Potential complications	<p>As for arterial cannulation</p> <p>Misleading results due to poor system set-up.</p>
6. Other information	<p>Less invasive CO devices are increasingly utilised as clinicians move away from pulmonary artery catheter insertion in ICU patients</p>

Cardiovascular - Circulatory assist devices



IABP insertion kit

1. Item name	Intra-aortic balloon pump (IABP)
2. Uses	Most widely used circulatory assist device. Used in a range of conditions in which the primary problem is cardiovascular dysfunction/cardiogenic shock (e.g. after myocardial infarction, during cardiac catheterization procedures, during cardiac surgery and to enable weaning from cardiopulmonary bypass). Used as a bridge to recovery or another rescue therapy.
3. Description	<p>The intra-aortic balloon (IAB) is made of a polyurethane membrane mounted on a vascular catheter. The catheters are of various sizes, usually 7.5 F with the balloon size being chosen on the basis of height (25–50 cc). The kits may be sheathed or sheathless and some newer catheters have fibreoptics that can aid pressure waveform detection and therefore timing.</p> <p>Helium is used to inflate the balloon as its low viscosity means there is little turbulent flow so the balloon can inflate fast and deflate slowly. It is also relatively benign and eliminated quickly if there is a leak or the balloon ruptures</p> <p>ehe</p>

4. Method of insertion and/or use	<p>A Seldinger technique is used to insert the balloon into the femoral artery. Fluoroscopy is recommended to ensure correct positioning, but blind insertion and use of a tape measure can be used in an emergency with imaging post procedure to ensure the balloon tip is 2–3 cm below the left subclavian artery, and that the proximal portion of the balloon is above the renal arteries. Most catheters have radiopaque distal and proximal markers.</p> <p>The IAB is positioned in the descending thoracic aorta just distal to the left subclavian artery and the IABP is timed to inflate and deflate in time with the cardiac cycle. Triggers include ECG (using the R wave to designate systole), arterial waveform (using the arterial upslope to designate systole), pacing modes (using pacing spikes to detect cardiac cycle events). In AF mode the balloon deflates when R waves are sensed. An internal trigger mode is available for asystolic arrested patients. Newer consoles have an automatic mode.</p> <p>The IAB is connected to an IABP console, and when inflated the balloon occludes 80–90% of the aorta.</p>
5. Potential complications	<p>Vessel related:</p> <p>Limb ischaemia</p> <p>Aortic dissection</p> <p>Retroperitoneal bleeding</p> <p>Femoral haematomas and pseudoaneurysms</p> <p>Balloon related:</p> <p>Incorrect position with vascular occlusion or inability to support failing cardiovascular system</p> <p>Balloon perforation (in cardiac arrest the balloon volume is reduced to help prevent balloon trauma)</p> <p>Gas embolisation</p> <p>Thrombocytopenia</p> <p>Infection</p>
6. Other information	<p>Inflation is at the onset of diastole, with displacement of blood in both directions causing enhancement of both coronary and systemic perfusion. Deflation occurs just prior to systole decreasing myocardial oxygen demand due to reduced systolic</p>

pressure and left ventricular wall stress.

The combined effects of inflation and deflation result in improved myocardial oxygenation, increased CO and perfusion to vital organs and a reduction in left ventricular workload.

Absolute contraindications: severe aortic regurgitation, aortic dissection

Relative contraindications: severe coagulopathy, peripheral vascular disease, known aortic aneurysm



ECMO circuit

1. Item name	Extracorporeal Membrane Oxygenation (ECMO)
2. Uses	To provide extracorporeal support for patients with reversible or treatable pathologies associated with severe pulmonary (VV ECMO) and/or cardiac failure (VA ECMO)
3. Description	Components: – Cannulae (drain and return; in adults 19–23 F venous and 17–19 F arterial)

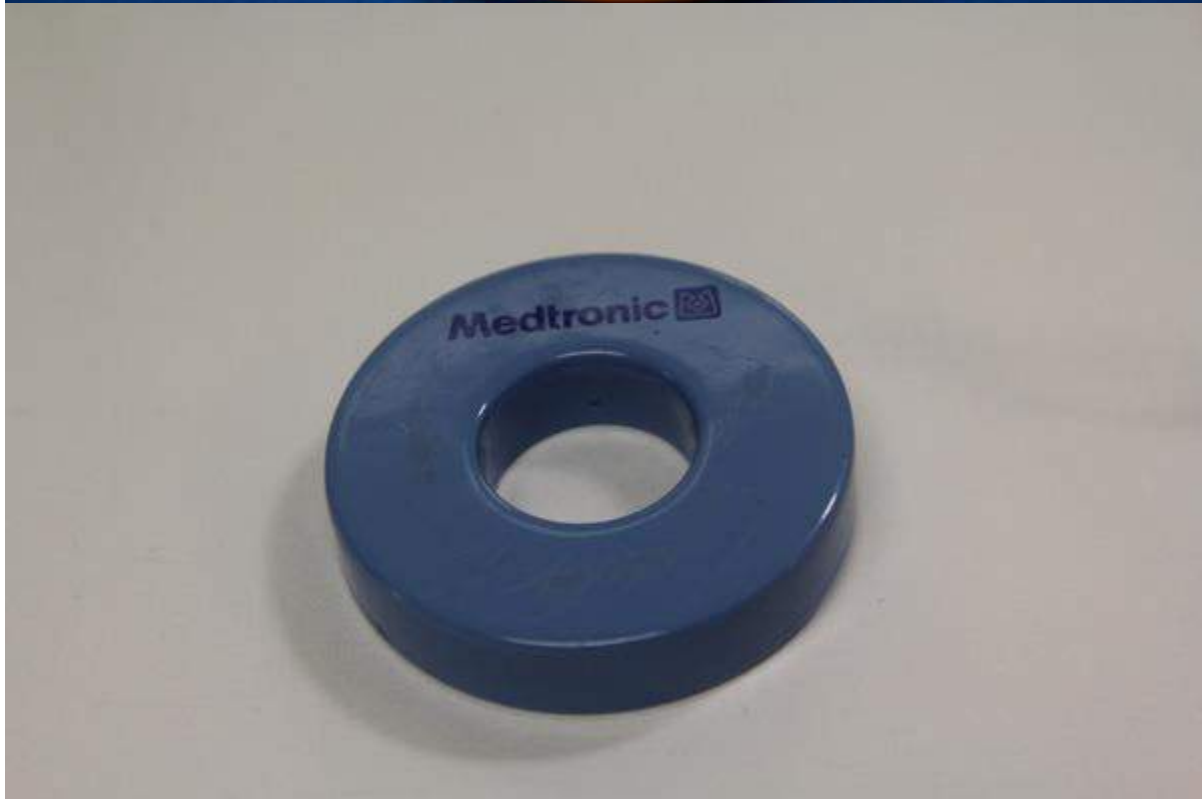
	<ul style="list-style-type: none"> – Circuit (may be heparin bonded to reduce the need for systemic anticoagulation) – Pump (centrifugal e.g. Jostra) – Oxygenator/blood warmer (e.g. hollow fibre membrane oxygenator such as the Quadrox made of durable polymethylpentene) – Flow sensors – flow rates commonly 2–5 L/min
4. Method of insertion and/or use	Cannulae and sites of insertion selected (e.g. VV ECMO – both femoral veins +/- internal jugular vein); circuit assembled and primed. Anticoagulation strategy selected (most commonly low–moderate dose heparin). Cannulae inserted, position confirmed (e.g. with echocardiography) and extracorporeal flow commenced.
5. Potential complications	Bleeding, thromboembolism, infection, cannulation related vessel injury, limb ischaemia and compartment syndrome, haemolysis, thrombocytopenia, SIRS and MODS, air embolism, accidental decannulation or disconnection, circuit component failure, inadequate LV decompression (VA ECMO); regional hypoxaemia (depending on cannula placement); inadequate flow to meet the needs of the patient; anticoagulation reactions (e.g. HIT)
6. Other information	VA ECMO can be performed with percutaneously inserted cannulae or at sternotomy with direct cannulation (e.g. right atrium and aorta). A small limb perfusion ‘back’ cannula is usually inserted when the femoral artery is cannulated.



VAD console

1. Item name	Ventricular Assist Device (VAD)
2. Uses	To provide extracorporeal cardiac support for the left (and/or right) ventricle (designated as LVAD, RVAD or BIVAD) as a bridge to recovery, bridge to transplant or as destination therapy in conditions causing severe heart failure
3. Description	<p>Range of devices – 3 types:</p> <ul style="list-style-type: none"> – Volume-displacement pump (e.g. Thoratec Heartmate XVE™) – Axial-flow pump (e.g. Jarvik 2000™; Thoratec Heartmate III/III™) – Centrifugal pump (e.g. HeartWare HVAD™) <p>Parts: a pump, a controller, power source (including mains attachment and batteries), percutaneous drive line connecting the pump to the external controller</p>
4. Method of insertion and/or use	<p>Cardiac surgical procedure</p> <p>Consoles and settings vary between devices</p>
5. Potential complications	Bleeding, thromboembolism, infection (acute and chronic, particularly associated with the cannula sites and drive line attachment), device component failure, HLA alloimmunisation (may be related to need for large numbers of blood product transfusions), negative psychological effects relating to body image
6. Other information	Development is ongoing with pursuit of a totally implantable, miniature device that may be inserted as an LVAD, RVAD or BIVADS, with a transcutaneous driver (no drive line) and power mechanism that requires minimal anticoagulation.

Cardiovascular - Pacing equipment



Pacing swan and Magnet

1. Item name	Temporary transvenous pacing wire
2. Uses	To assist management of bradydysrhythmias, tachydysrhythmias, permanent pacemaker failure, support after cardiac surgery and during diagnostic studies (e.g. in an electrophysiology laboratory).
3. Description	<p>The pacing lead can be bipolar or unipolar. With bipolar, 2 electrodes (positive and negative) are located in the heart, whereas with unipolar only one electrode (negative) is in direct contact with the myocardium. In both, the current flows from the negative terminal of the pulse generator, down the pacing lead to the negative electrode and into the heart. The current is then picked up by the positive electrode and flows back up the lead to the positive terminal of the pulse generator. The bipolar leads generally have the two electrodes on the same catheter with the distal/negative electrode at the tip in direct contact with the heart, and the positive electrode being about 1 cm up the lead from this.</p> <p>There are various types of wires: balloon tipped are designed for right ventricular (RV) placement and semi rigid are used with fluoroscopy (e.g. straight for RV placement or with a J tip to aid right atrial placement). Purpose specific straight wires can be inserted down a pacing swan atrial or ventricular port.</p>
4. Method of insertion and/or use	<p>Insertion has two parts:</p> <p>Cannulation of a central vein – a large bore cannula/sheath, large enough to accommodate the pacing wire is inserted. Some kits come with both the sheath and pacing wire or a PAC introducer sheath (e.g. 7 Fr) can be used. The internal jugular (especially the right) or subclavian vein (especially the left) sites are preferred as wire insertion follows the natural anatomic curves.</p> <p>Pacing wire insertion – the wire is fed through the sheath into the heart; once in about 15 centimetres (beyond the sheath) the end should be attached to the connector lead and then into the pulse generator. The wire is advanced (preferably with fluoroscopic visualisation for non-pacing swan wires) until the patients' intrinsic beats are sensed, and then electrical capture is obtained followed by the establishment of the sensing threshold. The position is confirmed by ECG to assess electrical capture and clinical assessment confirms mechanical capture. Fluoroscopy/CXR – for an RV wire the tip should lie in a gentle curve from right to left just across the midline.</p>
5. Potential complications	<p>Those related to central venous cannulation</p> <p>Those related to the pacing wire – myocardial perforation, pericardial tamponade, tricuspid valve injury, arrhythmias, infection</p> <p>Those related to pacing – failure to pace, failure to sense with R on T phenomenon, over sensing, pacemaker syndrome from loss of atrial kick</p>

6. Other
information

Important associated concepts:

Types of pacing

Transcutaneous pacing – may be useful until the situation resolves or transvenous pacing can be established (involves the use of two large skin electrodes, one placed anteriorly and the other posteriorly on the chest, connected to a pulse generator. Improved technology related to stimulus delivery and electrode pads that disperse the energy delivered more efficiently has helped reduce the pain associated with both cutaneous and muscle stimulation).

Epicardial pacing wires – used most commonly after cardiac surgery; usually inserted as pairs of unipolar leads on the right atrium and/or ventricle. If a unipolar lead fails to function then another 'indifferent' skin lead can be inserted to complete the electric circuit and restore pacing.

Permanent pacemakers/Implantable Cardioverter-defibrillators (ICDs) – permanent insertion of a pulse generator/cardioverter-defibrillator and pacing leads into the atria/ventricles; leads are usually placed in the endocardium transvenously but may be inserted surgically onto the epicardium. Variable responses occur in response to a praecordial **magnet** being applied, dependent on the brand (e.g. Medtronic devices revert to asynchronous pacing modes and may turn off anti-tachycardia functionality).



Pulse generator

1. Item name	Pulse generator box
2. Uses	For atrial, ventricular and sequential pacing
3. Description	<p>Designed to generate an electrical current that travels down the pacing lead and exits through an electrode (exposed part at tip of wire) that is in direct contact with the heart muscle. This current initiates myocardial depolarisation. The current then returns to the pulse generator to complete the circuit. The power source is a standard 9-volt alkaline battery; this should be changed prior to using the box and never whilst the generator is attached to a patient.</p> <p>There are various designs but generally all have dials for pacing rate (regulates the number of impulses delivered to the heart per minute), output (the amount of energy used to stimulate the heart), sensitivity determines the ability of the pacemaker to detect the hearts intrinsic activity). Most also have a locking feature that has to be overridden before changes to any of these can be made and so the box cannot be accidentally turned off.</p>
4. Method of insertion and/or use	<p>The pulse generator box is connected to the pacing wire(s) via a patient cable set that is inserted into the top of the generator. This set may be colour coded for the atrium and ventricle and matched for polarity. Once the pacing wires are in the correct position within the heart the knobs on the side of the cable connector block should be loosened so that the pins on the pacing wires can be inserted and then the knobs tightened to hold them in position. The generator is then turned on, and the mode of pacing selected if required (depending on the complexity of the generator). The rate is then set, followed by the output and then the sensitivity. Most pulse generators also have a panel that shows whether a chamber is being sensed, paced and the rate, along with a battery indicator.</p>
5. Potential complications	<p>Problems arising during insertion of a pacing wire (varies with technique)</p> <p>Failure to sense (to avoid R on T phenomenon with VT/VF, during and after insertion, ensure sensing is occurring before an output is delivered)</p> <p>Failure to capture</p> <p>Lead disconnection</p> <p>Failure to recognise low battery and cessation of pacing</p>
6. Other information	<p>Important associated concepts:</p> <p><u>Pacing nomenclature</u></p> <p>North American Society of Pacing and Electrophysiology (NASPE) and British Pacing and Electrophysiology Group (BPEG) uses a 5 position approach to describing pacing therapies</p> <p>1 = chamber paced</p>

2 = chamber sensed

3 = response to sensing

4 = other functions (e.g. programmability such as rate modulation)

5 = multisite pacing functions

Most common modes in temporary pacing devices in ICU are VVI, AAI, DDD

PVARP (Post Ventricular Atrial Refractory Period) = a setting on pulse generators that helps prevent pacemaker mediated tachycardia; a refractory period is set during which no atrial impulse (intrinsic or paced) is tracked to a ventricular output.

Cardiovascular - Defibrillation





Figure legend:

1. Power source with rectifier and transformer
2. Capacitor
3. Gate – 3a. position for charging; 3b. position for shock delivery
4. Inductor
5. Defibrillator pads
6. Thoracic impedance
7. User interface – On button, energy select, charging
8. Shock delivery button

1. Item name	Defibrillator
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2. Uses	<p>Provide electrical shocks of preset energy through the chest wall (expressed in joules) to the heart in an attempt to revert ventricular fibrillation (VF), and pulseless ventricular tachycardia (VT) during cardiac arrest.</p> <p>Synchronised shocks (cardioversion) are used in the management of VT with a pulse and other tachyarrhythmias.</p> <p>Some devices also have the capacity to provide transcutaneous pacing.</p>
3. Description	<p>There are various defibrillators available classified as:</p> <ol style="list-style-type: none"> 1. Monophasic defibrillators: deliver energy in one direction only using a dampened monophasic sinusoidal waveform, which is a single pulse lasting for 3–4 msec. The energy level used should always be set at a maximum in adults (360 J) for defibrillation. 2. Biphasic defibrillators: deliver energy in two directions using a variety of waveform technologies. Considered 'gold standard'. Produce bidirectional truncated transthoracic shocks that are much more efficient at lower energies than standard damped sine-wave shock-defibrillators. This results in less myocardial damage, fewer post-defibrillation ECG abnormalities and more effective first shocks. The energy level set for biphasic defibrillators will depend on the model (e.g.150–200 J for adults for defibrillation). <p>Key features: on/off button, energy select button, charge button, button to deliver a shock, button to dump any charge not needed, how to select the monitoring mode and which lead is the default, how to change from paddle to ECG monitoring; additional pacing features and controls, including rate and output.</p> <p>Automated external defibrillators (AEDs): have an internal microprocessor that analyses the ECG; if VF/VT are detected it causes the AED to display a warning and then either deliver a shock (automatic) or advise the operator to do so (semi-automatic). AEDS are highly accurate and may reduce the time to the first shock, are simple to learn and use, increasing their availability and application, including for public domains.</p>
4. Method of insertion and/or use	<p>Defibrillation is successful when a critical mass of myocardium is depolarised simultaneously. This means the fibrillation is interrupted and may allow recapture by a single pacemaker. For this to occur the transthoracic impedance must be minimised. Depolarisation of the myocardial cells is accomplished by passage of the electrical current through them. Australian and New Zealand Resuscitation Councils and European Resuscitation Council algorithms/guidelines are used for determining when defibrillation should be used and the number of shocks and energy levels used.</p> <p>Pads/paddles are 10–13 cm in size and applied carefully to the skin to ensure good adherence and no interruption to the energy delivered.</p> <p>The defibrillator is charged to the required energy and then the operator ensures that everyone has moved away from the patient before discharging. If paddles are used, a pressure of about 5</p>

	<p>kg is required and defibrillation should be done in expiration if possible.</p> <p>Shock delivery is confirmed by the patient's motor response and on the defibrillator/cardiac monitor.</p>
5. Potential complications	<p>Risk of electrical injury to rescuers and the patient in the presence of water, metal fixtures, oxygen, inflammable substances; the 'Stand clear!' command prior to discharge of shocks is essential to ensure safety.</p> <p>Paddles should only be charged when resting on the patient's chest.</p> <p>Avoid placement of pads/paddles over ECG leads, GTN patches, lines and implantable devices.</p> <p>If defibrillation is unsuccessful: recommence CPR, check paddle/pad position and chest wall contact, consider changing defibrillator pads or changing to the anteroposterior placement and ensure it is set to deliver an unsynchronised shock.</p>
6. Other information	<p>Important associated concepts:</p> <p>Charge = quantity of charge passing over a point over 1 sec when a current of 1A flows past that point (unit C = coulomb).</p> <p>Capacitance = the ability of a material to hold an electrical charge (unit F = farad; 1 farad = 1 coulomb/V).</p> <p>Capacitor = a device that stores electrical energy (the defibrillator capacitor builds up charge from the mains or battery supply when the charging switch is triggered and it is released when the discharge switch is activated).</p> <p>Inductor = a device that stores energy in a magnetic field created when current passes through it; on the defibrillator it controls the nature (waveform characteristics) and duration of the current.</p> <p>Rectifier = a device that converts AC to DC voltage (DC is less harmful to myocardium).</p> <p>Transformer = a device that transforms electrical energy from one circuit to another in order to increase or decrease the voltage in the second circuit ("steps up" the voltage from mains levels to the much higher level needed for the defibrillator capacitor to charge).</p> <p>Impedance = measure of opposition to AC current flow (factors include chest wall thickness, time between shocks and the firmness of the contact of the pad with the chest wall).</p> <p>Stored energy for defibrillation (J) = stored charge (C) × potential (V)</p> <p>(Stored energy ranges between devices but may be up to 400 J and the potential is in the order of 5000 V).</p>

Optimal current is 30–40 A; a shock of 200 J delivers about 30 A to the average patient, but it depends on the thoracic impedance of the individual patient; this may be too little or for others too much.

Some newer machines can measure thoracic impedance and adjust the energy delivered accordingly.



Defibrillation gel pads

1. Item name	Defibrillation pads
2. Uses	To facilitate cardioversion and defibrillation. Some also allow ECG monitoring and have the capacity to externally pace.
3. Description	<p>1. Gel pads – used to reduce transthoracic impedance when paddles are applied directly to the chest wall to deliver a shock. The packet containing the gel pads should not have been opened to ensure that the pads have not dried out. The pads are for single patient use but can be used for multiple shocks during the same resuscitation attempt. The pads not only limit transthoracic impedance but also protect the skin from being burnt.</p> <p>2. Multi-function electrode (MFE) pads or self-adhesive defibrillator pads/electrodes – more</p>

	<p>commonly used and allow monitoring, defibrillation and pacing without additional monitoring electrodes or the operator needing to come into direct contact with the patient.</p> <p>The sizes of the paddles/pads are also important with larger size associated with higher success rates and less myocardial damage. Paddles/pads of 10–13 cm seem to reduce transthoracic impedance most effectively. The MFE pads provide a greater surface area for energy delivery, deliver more reliable charge, reduce the skin complications from current delivery and are safer for staff. The transthoracic impedance seems to be similar whether gel pads or MFE pads are used.</p>
4. Method of insertion and/or use	<p>Positioning of the paddles/pads is important for the success of defibrillation. There are two accepted positions to optimize current delivery to the heart:</p> <p>Anteroapical – one pad/paddle is placed to the right of the sternum just below the clavicle, and the other is centred lateral to the normal cardiac apex in the anterior or midaxillary line (V5–6).</p> <p>Anteroposterior – the anterior pad/paddle is placed over the praecordium or apex, and the posterior pad/paddle is placed on the back in the left or right infrascapular region.</p> <p>When paddles are used the pressure exerted needs to be at least 5 kg.</p> <p>In applying either gel pads or MFE pads care needs to be taken to ensure that there is good contact between the pad and the skin (needs to be dry and clean) to enhance adherence and decrease the chance of arcing/burns. The skin should be shaved if needed and the pad should not be in contact with any other equipment including ECG dots, GTN pads, lines and cables.</p>
5. Potential complications	<p>Arcing (electricity is attracted from one electrode to the other and can result in explosive noises, burns and impaired delivery of current)</p> <p>Electrical injury to bystanders</p> <p>Risk of explosion if oxygen isn't not removed from the around the area of defibrillation during shock delivery</p> <p>Skin burns from repeated shock delivery</p> <p>Myocardial injury and post defibrillation dysrhythmias and 'stunning'</p> <p>Skeletal muscle injury or thoracic vertebral fractures</p>
6. Other information	<p>Transcutaneous pacing is also a feature of some defibrillators, most commonly used in conjunction with self-adhesive defibrillator pads.</p>

Cardiovascular - Fluid administration



Simple pressure bag

1. Item name	Rapid infusing systems
2. Uses	Used following major haemorrhage (e.g. major trauma, obstetric complications) or where major haemorrhage is expected (e.g. major vascular or liver surgery)
3. Description	<p>Various devices available of varying complexity such as:</p> <p>Rapid Infusion System (RIS TM) – this currently is the most efficient warming and infusion device available. It comprises a roller pump mechanism and heat exchanger and can deliver blood products at precise rates and under normothermic conditions at up to 1500 mL/min.</p> <p>Level 1 TM – a high capacity fluid warmer that minimises hypothermia associated with major fluid resuscitation. Water is heated to 40°C at the base of the warmer and then circulated through a closed-flow, aluminium counter-current heat exchanger that forms an integral part of its disposable giving sets. It is able to warm cold (10°C) packed red cells to temperatures >35°C at flows of 500 mL/min.</p> <p>Simple pressure bags – are composed of a sleeve that encircles a bag of fluid and contains an air filled chamber. This may be inflated by a hand pump, resulting in compression of the fluid bag and</p>

	increased rate of fluid flow through the attached infusion line.
4. Method of insertion and/or use	<p>Factors determining maximum possible flow during intravenous infusion include the cannulation site and cannula used, the type of administration set, the infusion pressure and the temperature of the fluid.</p> <p>Rapid infusion techniques incorporate short, large bore cannulae placed in large veins in combination with wide-bore infusion sets. Pressurising the system with automatic pressure infusers enclosed in rigid boxes can increase flow rates further.</p> <p>Whilst venous access is being established, the rapid infuser should be set up. The giving sets are disposable and are attached to the stand with the warmer mounted on it with the bottom end plugged through the heat exchanger and the top secured into the pressurized system. Priming is usually with crystalloid solution before the warmer is switched on. Once ready to use, the giving set is attached to the cannula and the infusion rates increased by placing the fluid bags/blood products in the automatic infuser boxes at the top of the level 1, and pressurising to 300 mmHg</p>
5. Potential complications	<p>Air embolism (an air detector and clamp is in all-purpose specific devices. They work using an ultrasonic signal that passes through the fluid filled filter continuously, a bolus of air will displace the fluid and break the signal so the clamp closes. This is linked to an audible alarm. The air can be removed easily without disconnecting from the patient.)</p> <p>Over transfusion</p> <p>Risk of large volumes being infused into perivascular space if problem with cannulation site</p>
6. Other information	These devices may take time to prime and set up so their use needs to be thought of early.



Blood warmer

1. Item name	Blood warmer
2. Uses	Used with rapid transfusion rates (e.g. >50 mL/kg/hr), in already hypothermic patients or rare conditions where cold fluid delivery is problematic (e.g. known cold agglutinins)
3. Description	<p>There are three main types/methods:</p> <p>Water-bath warmers – warms IV fluid with prewarmed water. Maximum temperature is 38°C and whilst cheap the system is inefficient at high infusion rates.</p> <p>Dry heat plate warmers – increases heat transfer capability of the material and enables an increase in temperature up to 41°C. The IV fluid is warmed in a cassette between the heat plates.</p> <p>Intravenous fluid tube warmers – warm the fluid in a specially designed tube. The tube has a central lumen with an internal diameter of 3 mm. An outer layer through which warm water circulates down one side and then up into a reservoir surrounds this. Tubing is heavy and long and only efficient at low flow rates (20–30 mL/min).</p> <p>Each requires a specially designed IV tube warmer coil.</p> <p>The ability to impart heat to fluid is a function of the power of the heating device. The metals used in the dry</p>

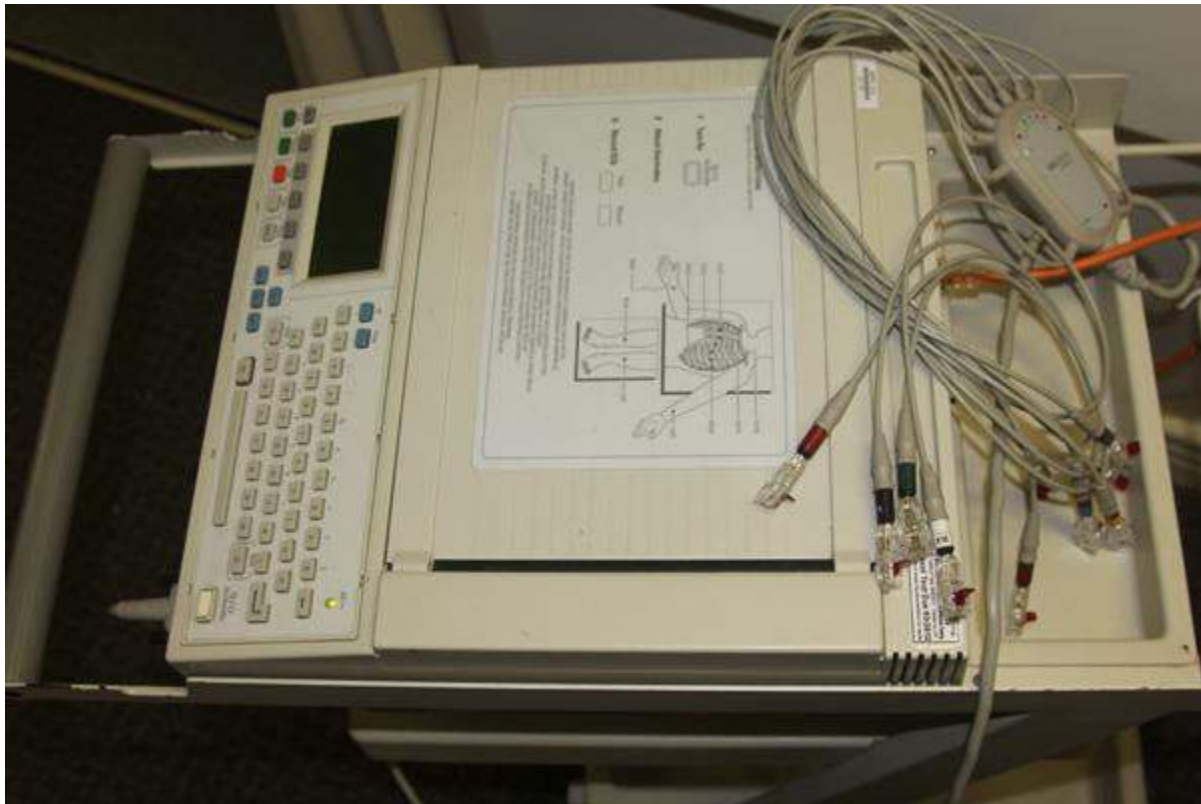
	<p>heat plate warmer are better heat conductors than the fluids used in the other two systems. This means that although at low flow rates the IV fluid warmers are the most efficient, if higher flow rates are necessary a device using a dry heat plate is far more effective.</p>
4. Method of insertion and/or use	<p>The routine warming of blood is not necessary. If warming is clinically indicated a specifically designed commercial device should be used with both visible and audible alarms, to ensure that the blood is not heated above 41°C. Blood warmers should be regularly serviced and maintained, as they can be very dangerous if they malfunction. Blood should never be warmed by any other method.</p>
5. Potential complications	<p>Overheating of blood (risk of haemolysis)</p> <p>Air embolism</p>
6. Other information	<p>The benefits of warming blood in massive transfusion are related to the avoidance of hypothermia and its accompanying adverse effects.</p>



Assembled Minijet of adrenaline and Unassembled Minijet of calcium chloride

1. Item name	Mini-jets™
2. Uses	Used in Cardiac Arrests and other Emergency situations to allow rapid delivery of resuscitation drugs.
3. Description	<p>Pre-filled Emergency drug delivery devices in doses commonly recommended in resuscitation algorithms. Advantages are rapid readiness for use and reduced risk of needlestick injury.</p> <p>The syringes are standard in design although they vary in size depending on the commonly recommended dose. Boxes are colour coded to allow recognition of the different drugs. The syringes have markings on the side to assist dose delivery.</p>
4. Method of insertion and/or use	Once the box is opened the Minijet™ has to be assembled. This requires removal of all the yellow parts, which include a cap on the syringe end and a plug on the drug ampoule. Once these are removed the drug ampoule is screwed carefully into the syringe device for delivery. Once in position the Minijet™ is plugged into the intravenous access port available (luer connection) and the drug delivered as with a normal syringe.
5. Potential complications	<p>Failure to assemble the Minijet™ properly and loss of some of drug prior to reaching patient from overscrewing</p> <p>Extravasation if injected with too much force</p> <p>Sharp injury from the end of the syringe</p>
6. Other information	Need to balance ease of use with cost and expiry if not used frequently

Cardiovascular - Miscellaneous



ECG machine and ECG dots

1. Item name	ECG machine and dots
2. Uses	ECG recordings are graphical outputs of the electrical activity of the heart. ECG dots/electrodes are placed on the skin to pick up the current generated in the heart muscle. Used for diagnosis of acute or chronic abnormalities by virtue of characteristic deviations in rate, rhythm and/or morphology of recordings in one or more leads.
3. Description	<p>ECG machines/modules – detect, amplify and record the electrical potentials generated by the heart. The print out is a graph of voltage (y axis; 1mV per cm) versus time (x axis; usually 25 mm/s so a large square is 400 ms and small square 40 ms); the display may be changed, but is commonly a 12 lead output, with a sample of each lead (limb, augmented limb then V leads) in columns is presented with a rhythm strip at the bottom (e.g. lead II). High and low pass filters can improve the signal and are used more commonly with continuous monitoring remove noise from the environment during patient care. Special algorithms allow interpretation, detection of pacing spikes and some track ST segments continuously for ischaemia (e.g. PhillipsTM ST Map software).</p> <p>ECG electrodes – various types depending on the brand and indication. Generally all are made of material that provides a constant area of contact to the skin associated with a gel that is hypoallergenic, highly conductive, lowers the skin resistance and has suitable adhesive properties. The sensors embedded in the electrode are made of silver/silver chloride. Most defibrillation pads also allow ECG recording.</p>
4. Method of insertion and/or use	<p>For a standard 12 lead ECG the dots used are for short-term use only (e.g. one recording then removed).</p> <p>For longer term ECG monitoring a 3 or 5 lead electrode system is used. These electrodes have features such as being made from soft material, low-profile microporous material so the skin can breathe and special adhesive backing material preventing the absorption of fluids. Larger size and good adhesives ensure optimal signal quality. Skin preparation with alcohol cleaning and hair removal may ensure that dots stick well and a good ECG is obtained.</p> <p>The leads are applied in conventional designated positions, often illustrated on the machine and/or labelled on the cable where it attaches to the electrode. Colour codes may also be used to assist rapid application of leads.</p> <p>Lead placement can deliberately be varied to detect specific issues (e.g. right sided conformation if suspected posterior myocardial infarction or dextrocardia).</p> <p>The ECG speed can be changed to improve interpretation of dysrhythmias (e.g. a half speed ECG can facilitate the detection of AV dissociation (P waves) in a broad complex tachycardia where VT and SVT with aberrant conduction are the differential diagnosis)</p>
5. Potential complications	Skin injury – allergic reaction to the electrode; injury from adhesive sticking to frail skin then being

	<p>removed</p> <p>Incorrect lead placement</p> <p>Poor ECG recording due to poor signal transmission or excess noise</p> <p>Incorrect interpretation</p> <p>Some life-threatening pathologies do not produce ECG changes or are not picked up unless the event is occurring at the time of the recording (e.g. myocardial ischaemia)</p>
6. Other information	<p>Important associated concepts:</p> <p>Measuring systems must produce signals that are both accurate and precise.</p> <p>Accuracy = the signal detected and displayed reflects the true signal produced (ie. is reliable)</p> <p>Precision = a signal that is consistently produced is consistently detected and displayed (ie. is reproducible)</p> <p>For an ECG this depends on patient factors (e.g. thickness of the chest wall and adherence of the electrodes, movement, tremor and shivering artefact) and equipment factors (e.g. use of noise filters and signal amplifiers, presence of external noise such as from diathermy)</p>



Pericardiocentesis kit

1. Item name	Pericardiocentesis kit
2. Uses	Removal of fluid from the pericardial space. This may be indicated as an emergency in acute tamponade or may be for chronic pericardial effusions where the fluid has accumulated more slowly, and can be for therapeutic or diagnostic reasons.
3. Description	<p>There are various Seldinger kits available, but all have the same main components:</p> <ol style="list-style-type: none"> 1. A needle to enter the pericardium. Thin walled 9–15 cm needles in most kits. Although some clinicians prefer a 16 G 9–15 cm over-the-needle catheter and a 3-way tap, or 14G long spinal needle 2.30 mL syringe 2. Appropriate guidewire and introducer 3.8–9 FG catheter with side holes (or pigtail catheter for chronic drainage (can have straight or curved ends) <p>Other equipment is an ultrasound machine/echo to allow drainage under direct vision. ECG electrodes, leads and monitor. Some kits have crocodile clips that attach to the needle and record the V lead of the ECG to provide early warning of contact with the myocardium.</p>
4. Method of insertion and/or use	If acute tamponade as much fluid as possible is aspirated. Unlike intracardiac blood, fluid from the pericardium usually does not clot. Once the patient improves with increased blood pressure aspiration should be stopped and a drain left in situ unless acute tamponade recurs.
5. Potential complications	<p>Perforation of right ventricle (RV) or atrium</p> <p>Perforation of left ventricle</p> <p>Laceration of the right coronary artery (especially the marginal branches)</p> <p>Pneumothorax</p> <p>Puncture of the peritoneum with infection and trauma to the abdominal organs</p> <p>Ventricular dysrhythmias</p> <p>Vasovagal reactions with bradycardia on pericardial puncture</p>
6. Other information	<p>Those with small effusions or those that have had previous cardiac surgery are at increased risk for perforation of the RV during the procedure. Thin-walled intravenous type cannulae have a tendency to break and should be left in the pericardial space for a short time only. Catheters are preferable.</p> <p>The procedure is associated with significant morbidity and a number of specialists prefer to use an open technique, reserving the percutaneous technique for emergencies.</p>



FemoStop™

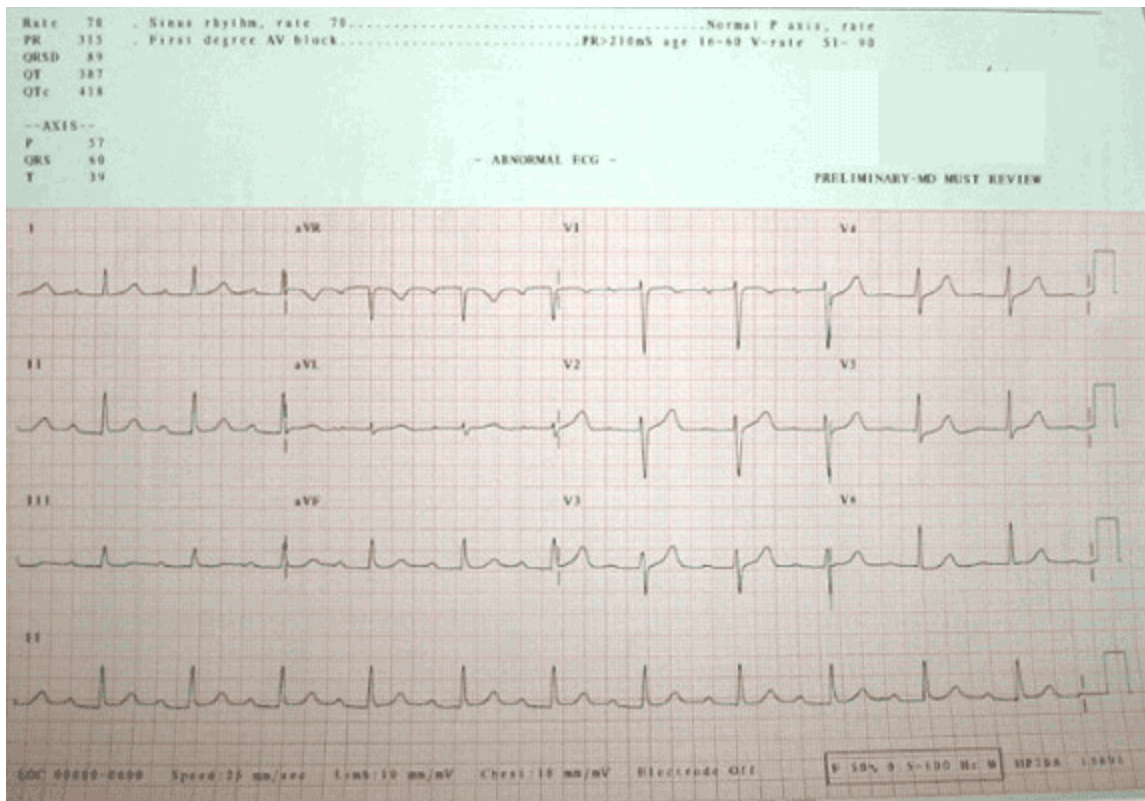
1. Item name	Femoral vessel compression device
2. Uses	To assist hands-free haemostasis after removal of femoral arterial and/or venous sheaths used for percutaneous procedures (e.g. angiography, venography)
3. Description	<p>Purpose specific design that includes several features (e.g. FemoStop Compression Assist Device™):</p> <ul style="list-style-type: none"> – Support arch that rests across the patient's pelvis – Adjustable belt that runs under the patient and enables fitting to different sized patients – Side arm levers for adjustment of the belt – Transparent inflatable, disposable dome with a sterile surface that sits over the puncture site – Integrated manometer to enable monitored inflation pressure
4. Method of insertion and/or use	The belt is inserted under the patient. A dome and pump is attached to the support arch to apply across the patient. Remove the dressing and sutures and apply antiseptic to the region then apply the dome just above and medial to the puncture site.

	<p>Remove the sheath:</p> <p>Venous – inflate to 20–30 mmHg as sheath removed and dome applied</p> <p>Arterial – inflate to 20 mmHg above patient's systolic blood pressure initially (limb will be pulseless during this period) then deflate 15 mmHg every 15 mins until 40mmHg reached</p> <p>Some units advocate a period of manual pressure to achieve haemostasis prior to applying the dome.</p> <p>Continuous observation and monitoring is necessary.</p>
5. Potential complications	<p>Vasovagal reactions</p> <p>Pain from pressure (may need to provide adjunctive analgesia/sedation)</p> <p>Need for immobility in bed for several hours</p> <p>Poor fit in obese patients</p> <p>Bleeding and haematoma formation if inadequate positioning, use of pressure and/or persistent coagulopathy</p> <p>Distal limb ischaemia</p> <p>AV fistula formation (increased risk if venous and arterial sheaths are removed together; should remove the venous sheath first and wait haemostasis prior to removal of the arterial sheath)</p>
6. Other information	<p>Alternative vascular closure devices are being increasingly utilised (e.g. Datascope Vasoseal™ where a femoral plug is delivered to the puncture site at the end of the procedure)</p>

ECG – Case 1

Question:

List 4 conditions associated with this abnormality



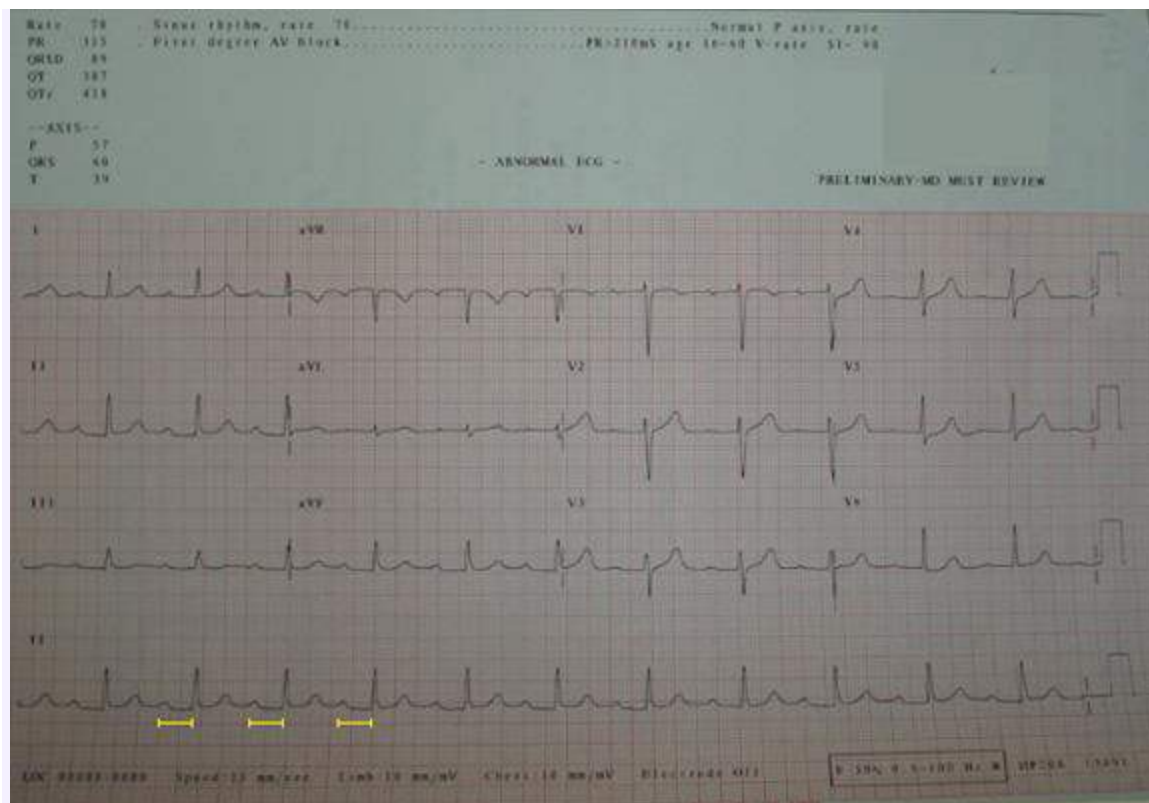
Answer:

Diagnosis = 1st degree heart block

Associated conditions

1. Normal variant
2. Inferior AMI
3. Myocarditis
4. Digoxin toxicity

Also, any cause of increased vagal tone



Rate = 76bpm.

Normal axis.

Sinus rhythm with prolonged PR segment (8 small boxes, or 0.32s – yellow bars)

Normal QRS and QT duration

Normal P, QRS and T wave morphology

examination INTENSIVE CARE

Equipment Cardiovascular Respiratory Renal Gastroenterology Neurology Infection control Other Practical & procedural skills Central venous line insertion Arterial line insertion Pulmonary artery catheter insertion Intra-aortic balloon pump insertion Defibrillation/Electrical Cardioversion Transcutaneous pacing Temporary transvenous pacing wire insertion Pericardiocentesis Intra-osseous needle insertion Standard intubation via the oral route Laryngeal mask insertion Cricothyroidotomy Percutaneous tracheostomy Emergency thoracocentesis Chest drain insertion Small bore catheter insertion Diagnostic bronchoscopy Nasogastric tube insertion Minnesota tube insertion Lumbar puncture Data interpretation Microbiology Transcranial doppler studies Electroencephalography Intracranial pressure monitoring Cardiocography Critical care literature Airway management Anaesthesia Cardiovascular medicine Ethics Fluids and electrolytes Gastroenterology Haematology/transfusion Monitoring devices Neurology Obstetrics and Gynaecology Pain

medicine Perioperative medicine Quality Renal medicine Respiratory medicine Resuscitation and cardiac arrest Sedation Sepsis Steroids Toxicology Trauma Paediatric Critical Care Literature **Recall cases**

Lab data cases Lab data – Case 1 Lab data – Case 2 Lab data – Case 3 Lab data – Case 4 Lab data – Case 5 Lab data – Case 6 Lab data – Case 7 Lab data – Case 8 Lab data – Case 9 Lab data – Case 10 Lab data – Case 11 Lab data – Case 12 Lab data – Case 13 Lab data – Case 14 Lab data – Case 15 Lab data – Case 16 Lab data – Case 17 Lab data – Case 18 Lab data – Case 19 Lab data – Case 20 Lab data – Case 21 Lab data – Case 22 Lab data – Case 23 Lab data – Case 24 Lab data – Case 25 Lab data – Case 26 Lab data – Case 27 Lab data – Case 28 Lab data – Case 29 Lab data – Case 30 Lab data – Case 31 Lab data – Case 32 Lab data – Case 33 Lab data – Case 34 Lab data – Case 35 ECG data cases ECG – Case 1 ECG – Case 2 ECG – Case 3 ECG – Case 4 ECG – Case 5 ECG – Case 6 ECG – Case 7 ECG – Case 8 ECG – Case 9 ECG – Case 10 ECG – Case 11 ECG – Case 12 ECG – Case 13 ECG – Case 14 ECG – Case 15 ECG – Case 16 ECG – Case 17 ECG – Case 18 Imaging data cases Imaging data – Case 1 Imaging data – Case 2 Imaging data – Case 3 Imaging data – Case 4 Imaging data – Case 5 Imaging data – Case 6 Imaging data – Case 7 Imaging data – Case 8 Imaging data – Case 9 Imaging data – Case 10 Imaging data – Case 11 Imaging data – Case 12 Imaging data – Case 13 Imaging data – Case 14 Imaging data – Case 15 Imaging data – Case 16 Imaging data – Case 17 Imaging data – Case 18 Imaging data – Case 19 Imaging data – Case 20 Imaging data – Case 21 Imaging data – Case 22 Imaging data – Case 23 Imaging data – Case 24 Imaging data – Case 25 Imaging data – Case 26 Imaging data – Case 27 Imaging data – Case 28 Imaging data – Case 29 Imaging data – Case 30 Imaging data – Case 31 Imaging data – Case 32 Imaging data – Case 33 Imaging data – Case 34 Imaging data – Case 35 Imaging data – Case 36 Imaging data – Case 37 Imaging data – Case 38 Monitoring data cases Monitoring data – Case 1 Monitoring data – Case 2 Monitoring data – Case 3 Monitoring data – Case 4 Monitoring data – Case 5 Monitoring data – Case 6 Monitoring data – Case 7 Monitoring data – Case 8 Monitoring data – Case 9 Monitoring data – Case 10 Monitoring data – Case 11 Monitoring data – Case 12 Monitoring data – Case 13 Monitoring data – Case 14 Monitoring data – Case 15 Monitoring data – Case 16 Monitoring data – Case 17 Monitoring data – Case 18 Monitoring data – Case 19 Monitoring data – Case 20 Monitoring data – Case 21 Clinical cases Clinical case 1 Clinical case 2 Clinical case 3 Clinical case 4 Clinical case 5 Clinical case 6 Clinical case 7 Clinical case 8 Clinical case 9 Clinical case 10 Clinical case 11 Clinical case 12 Clinical case 13 Clinical case 14 Clinical case 15 Clinical case 16 Clinical case 17 Clinical case 18 Clinical case 19 Clinical case 20 Clinical case 21 Clinical case 22 Clinical case 23 Clinical case 24 Clinical case 25 Clinical case 26 Clinical case 27 Clinical case 28 Clinical case 29 Clinical case 30 Clinical case 31 Clinical case 32 Clinical case 33 Clinical case 34 Paediatric Case Paediatric Case 1 Paediatric Case 2 Paediatric Case 3 Paediatric Case 4 Paediatric Case 5 Paediatric Case 6 Paediatric Case 7 Paediatric Case 8 Paediatric Case 9 Paediatric Case 10 Paediatric Case 11 Paediatric Case 12 Paediatric Case 13 Paediatric Case 14 Paediatric Case 15 Paediatric Case 16 Paediatric Case 17 Paediatric Case 18 Paediatric Case 19 Paediatric Case 20 Paediatric Case 21 Paediatric Case 22 Paediatric Case 23 Paediatric Case 24 Paediatric Case 25 Paediatric Case 26 Paediatric Case 27 Paediatric Case 28 Paediatric Case 29 Paediatric Case 30 Index of cases Lab data ECG data Imaging data Monitoring data Clinical photo cases Paediatric cases Trial Exam

Blank template Abdominal catastrophe Abdominal catastrophe with VAC dressing Cardiogenic shock High frequency oscillatory ventilation (HFOV) Multiorgan failure (MOF) Polytrauma Traumatic brain injury (TBI) Obstetric Post CABG or valve surgery

Quizzes / Recall Cases > ECG data cases - ECG – Case 2

03:44

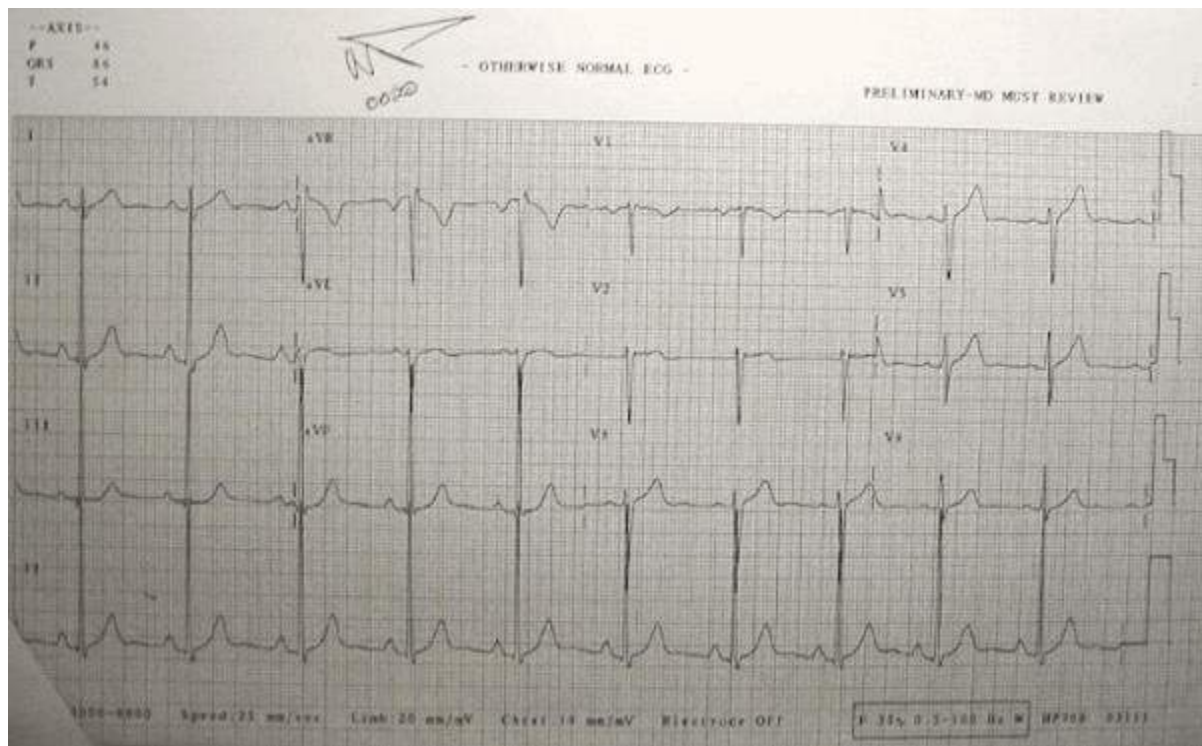
- ECG – Case 1
- ECG – Case 2
- ECG – Case 3
- ECG – Case 4
- ECG – Case 5
- ECG – Case 6
- ECG – Case 7
- ECG – Case 8
- ECG – Case 9
- ECG – Case 10

- ECG – Case 11
- ECG – Case 12
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- ECG – Case 17
- ECG – Case 18

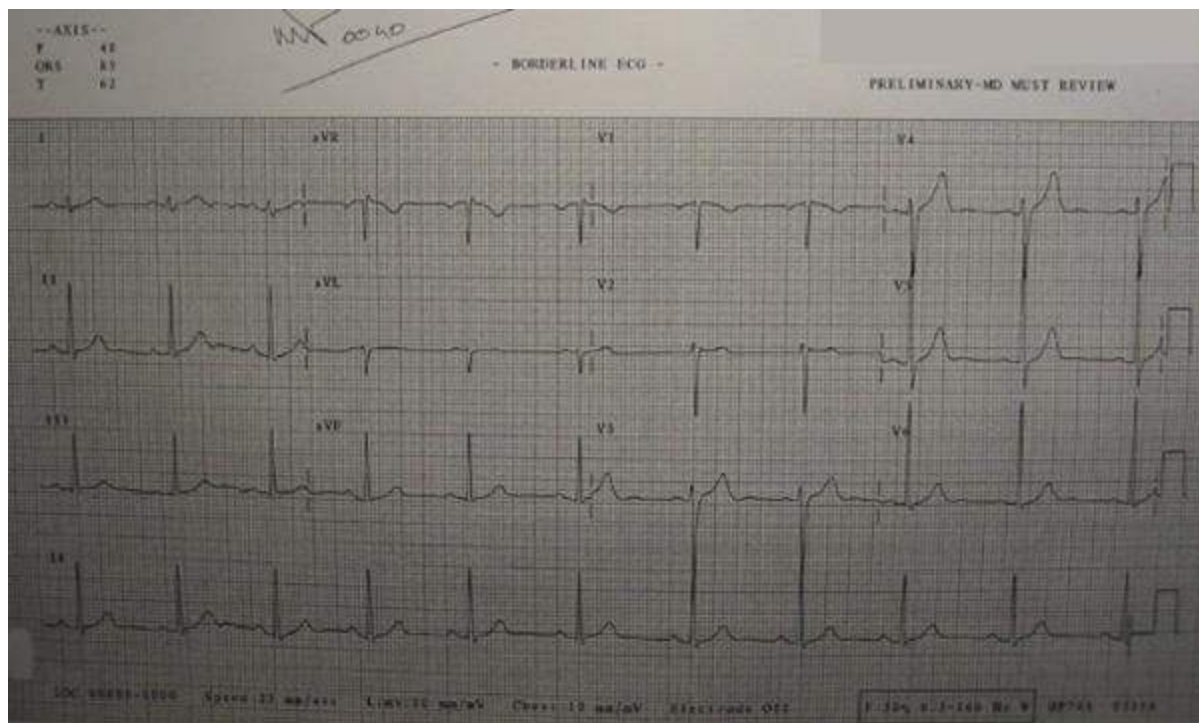
ECG – Case 2

Question:

- a) Describe the features of this ECG



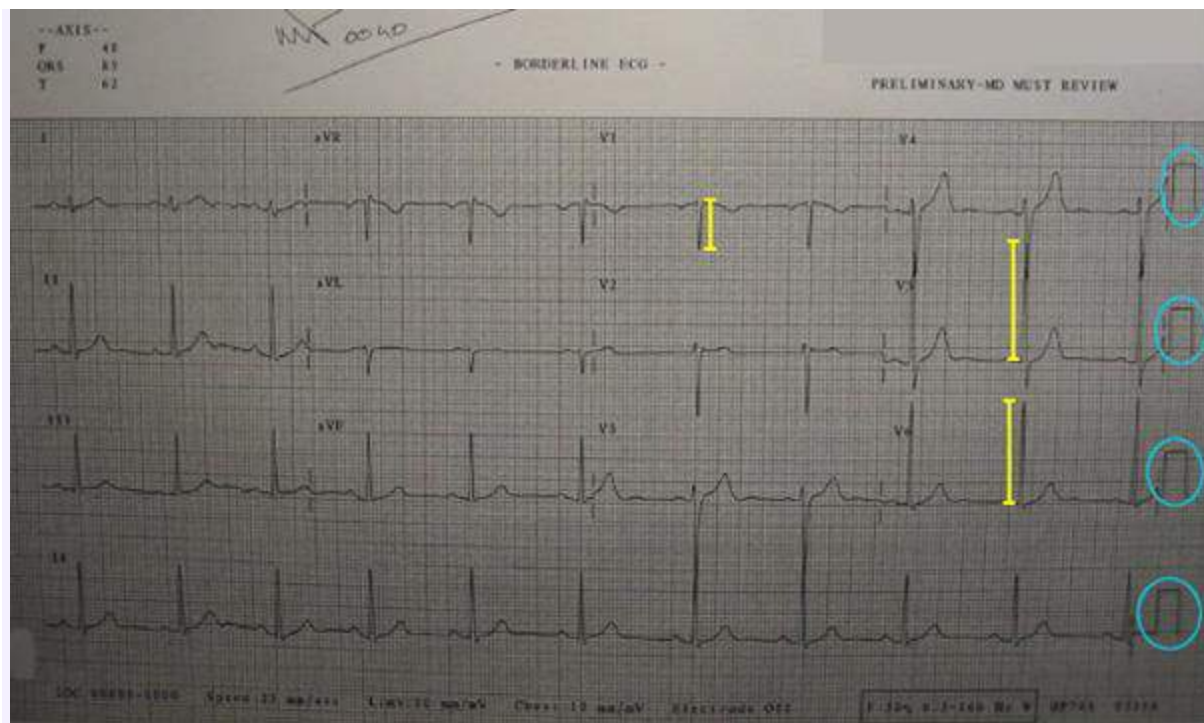
- b) With the voltage calibration corrected, describe the ECG as shown below



Answer:

Description: There is a voltage calibration error (yellow circles), resulting in distortion of the height of the P and T waves and the QRS complexes. The paper speed is correct (25mm/sec), so the rhythm is sinus at about 60bpm.

Diagnosis = Voltage calibration error



Voltage criteria for LVH

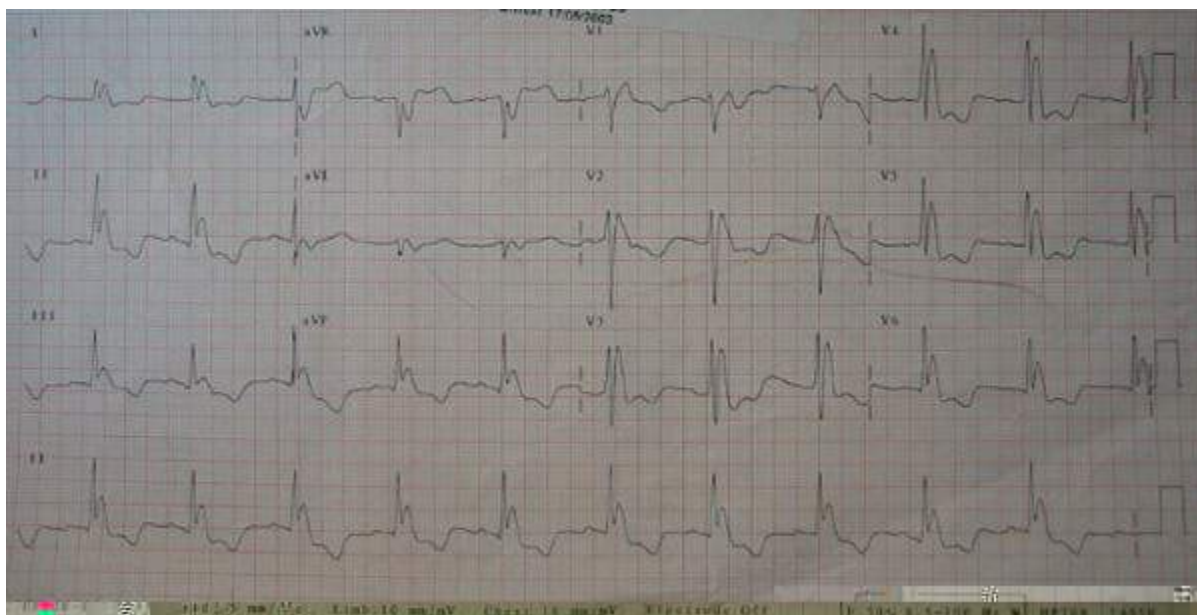
There are a variety of voltage criteria used to identify LVH, with specificities that are generally good (86 - 100%) but with poor sensitivities (1.5 - 55%). They include:

- S wave in V1 + R wave in V5 or V6 > 35 mm if age > 40yo, > 40 mm if age 30 to 40yo, > 60 mm if age 16 to 30yo (Sokolow-Lyon indices; sensitivity 40%, specificity 95%) (yellow bars).
- R wave in I + S wave in III > 25mm
- R wave in aVL > 11mm
- R wave in aVF > 20mm
- R wave in V5 or V6 > 26mm

ECG – Case 3

Question:

List 3 measures that are used to manage the condition indicated by the following ECG.



Answer:

Diagnosis = Hypothermia

Management:

1. Warm air blanket; e.g. Bair hugger
2. Warmed IV fluids
3. Warmed, humidified oxygen

Depending upon the severity of the hypothermia and the stability of the patient's condition, additional therapeutic modalities include warm fluid gastric lavage, warm fluid bladder irrigation, warm fluid peritoneal lavage, dialysis, endovascular warming catheter and cardiopulmonary bypass.

Rationale

Description

Borderline sinus bradycardia at 60bpm

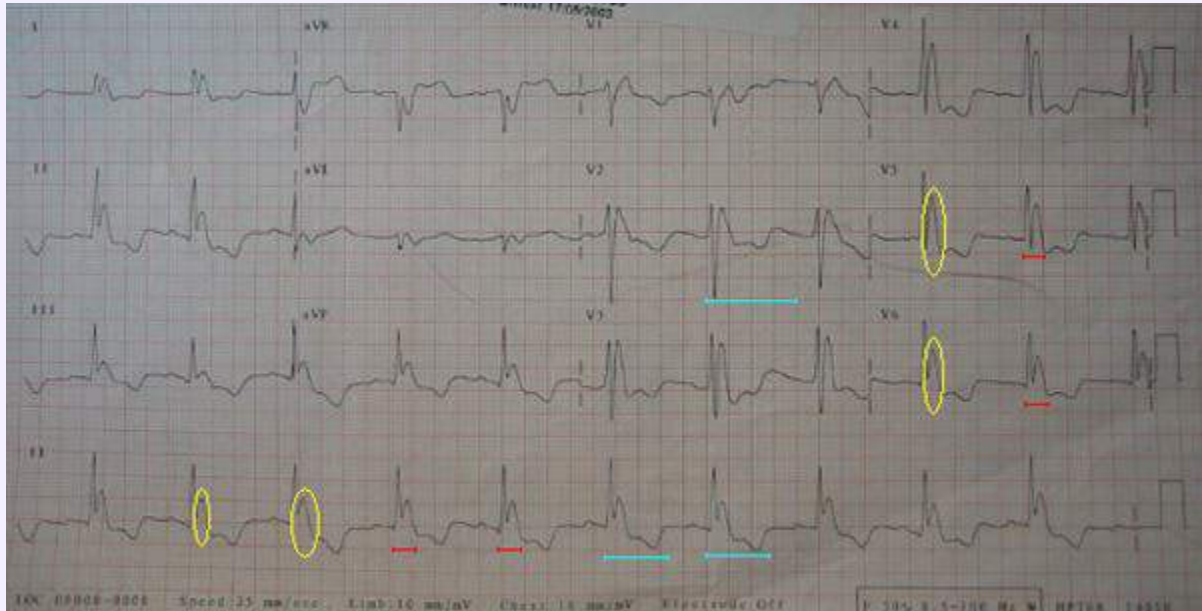
Normal axis

Prominent J-waves (Osborne waves – yellow circles) which indicate severe hypothermia (the height of the J-waves roughly correlates with the severity of the hypothermia).

Widened QRS complex (red bars), predominantly due to the J-waves

Widened QT segment (blue bars)

The PR segment is also often prolonged in hypothermia, but not in this case



ECG – Case 4

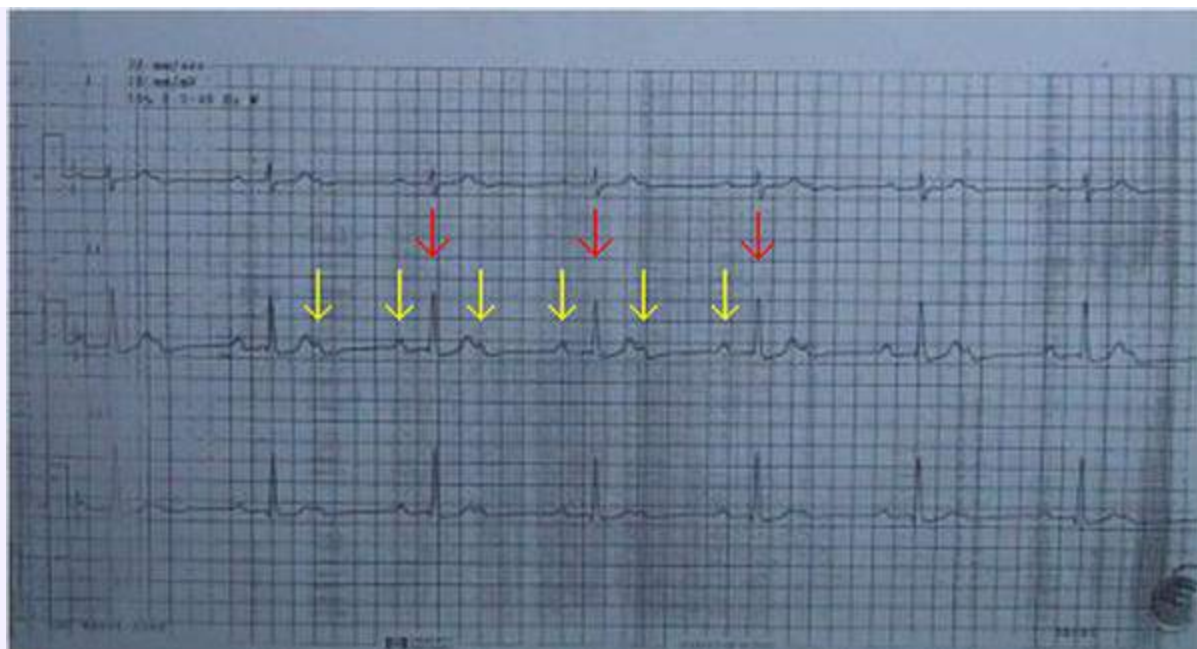
Question:

What associated pathology would you check for given the features of this ECG?

Answer:

Diagnosis = Mobitz type II 2nd degree heart block with 2:1 block

Associated pathology: Evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)



Description:

A normal morphology QRS complex (red arrows) follows every second P wave (yellow arrows) at regular intervals.

The P waves are spaced at regular intervals and are of normal morphology (as they originate from the sinus node)

The ventricular rate is approximately 40bpm

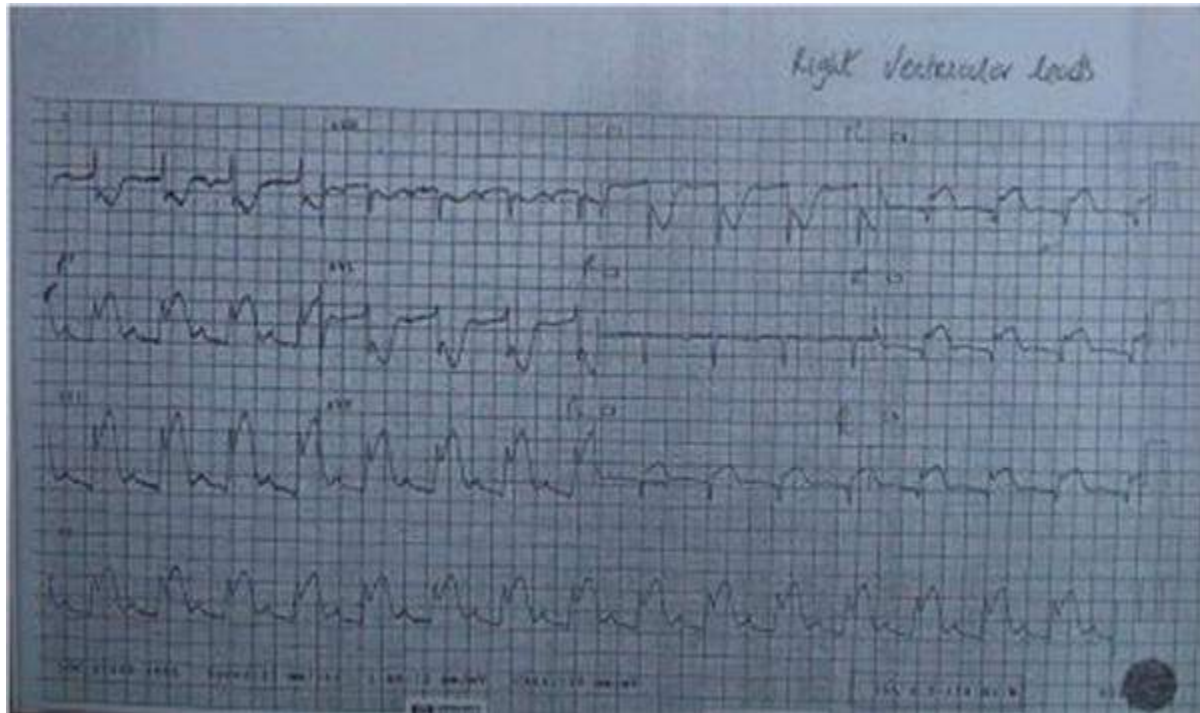
The axis is normal

There is no evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)

ECG – Case 5

Question:

What are the principles of managing this condition?



Answer:

Diagnosis = Right ventricular acute myocardial infarct with posterior extension and first degree heart block

Principles:

1. Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.
2. Hypotension is common and treated with volume resuscitation. Once euvolaemic, dobutamine may benefit. Cannot use CVP to guide volume status as it is elevated due to a failed right ventricle.
3. Analgesia – avoid nitrates, which can precipitate severe hypotension
4. Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)

Description

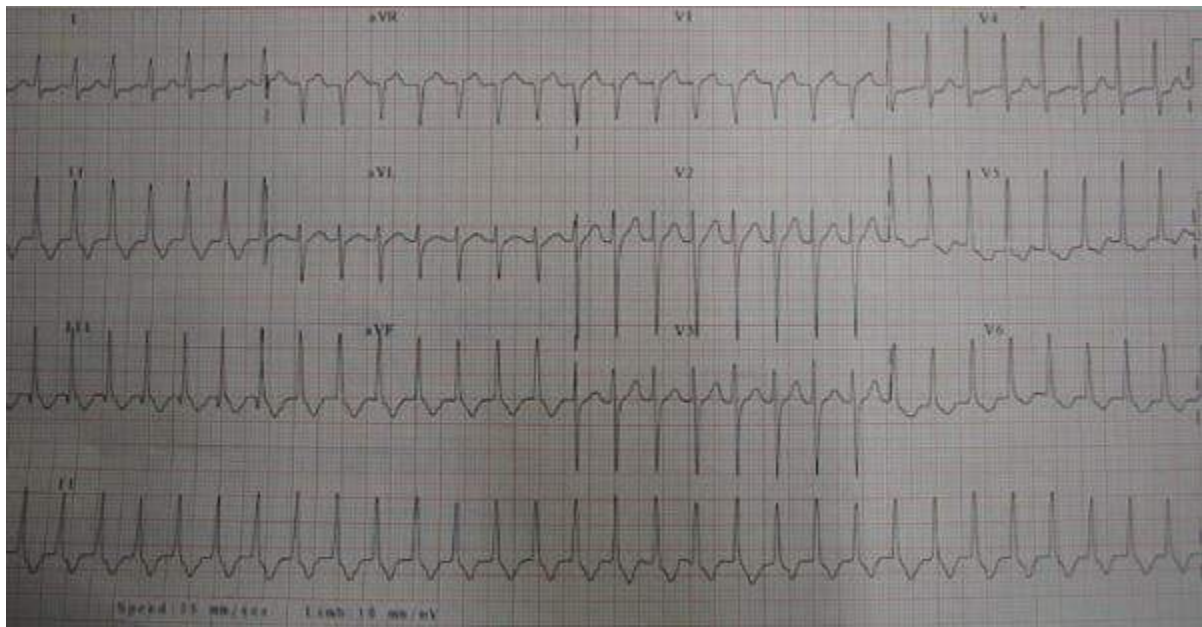
Significant ST elevation with hyperacute T waves in the inferior leads (II, III and aVF; yellow circles). Any inferior ischaemic event should prompt a search for

- A heart block – in this case there is a 1st degree heart block (green bars)
- A right ventricular AMI, especially if the ST elevation in lead II is higher than lead II, by performing a right ventricular ECG (red ellipse) where V 1 – 6, or just V4 alone, are placed in a mirror image position to their usual place on the chest and labelled V1R – V6R. The V4R to V6R leads (blue circles) demonstrate a similar appearance to a lateral AMI, but as they lie over the right ventricle, reflect an RV infarct.
- A posterior AMI (white ellipse) – flip the ECG over and bottom edge up and the waveform will look like a typical ST elevation AMI, or, perform a 15 lead ECG where leads V7 to V9 continue around from V6 to the posterior aspect of the chest.

ECG – Case 6

Question:

List 4 methods of treating this arrhythmia.



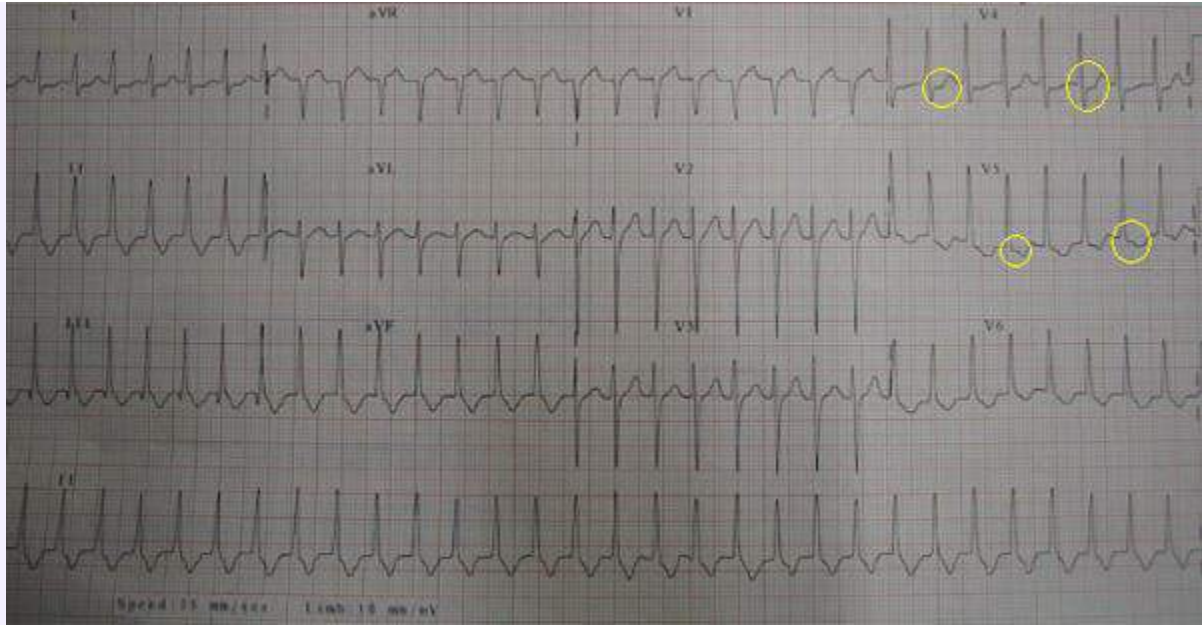
Answer:

Diagnosis = SVT (AVNRT)

Treatment

- Synchronised cardioversion (If hypotensive, evidence of cardiac ischaemia, evidence of heart failure or failed drug therapy. Potentially harmful if the SVT is due to digoxin toxicity.)
- Vagal manoeuvre – e.g. carotid massage, facial cold water immersion, Valsalva manoeuvre
- Adenosine IV in increments of 6mg to a maximum of 18mg, as a rapid bolus
- Verapamil 5mg IV over 1 – 2 minutes, unless accessory pathway (AVRT – see below) suspected

Additional alternatives include IV propranolol 0.5 – 1mg IV over 1 minute repeated every 5 minutes, metoprolol 5mg over 1 – 2 minutes every 5 minutes and external overdrive pacing at the SVT rate + 40bpm for 10 beats at 120mA.



Description

A regular narrow complex tachycardia with a ventricular rate of approximately 180bpm (therefore less likely to be atrial flutter, which usually runs at 150 or 300bpm)

There are no visible P waves, suggesting that this is an AV nodal re-entrant (AVNRT) SVT.

An AV re-entrant (AVRT) SVT is composed of an accessory pathway and the AV node, which requires the electrical impulse to travel between the two; orthodromic if it travels from AV node to accessory pathway and antidromic in the opposite direction. The resultant P wave is therefore usually seen after the QRS complex; i.e. the retrograde P wave, which shows up as a small negative deflection between the QRS complex and the T wave, or as a dent in the upstroke of the T wave. However, it may be difficult to confidently differentiate an AVRT from an AVNRT and it would make you less enthusiastic about using verapamil for chemical cardioversion.

ECG – Case 7

Question:

Please interpret the sequence of events in this rhythm strip. What underlying ECG deficit would you look for?



Answer:

Diagnosis = VPC resulting in R-on-T induced Torsades de pointes (polymorphic VT) at the start of the upper rhythm strip and subsequent cardioversion near the middle of the lower rhythm strip. There is no evidence of a large voltage spike prior to the cardioversion, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of $MgSO_4$.

I would look for a prolonged QT segment on the post reversion ECG. It is not evident on this strip.



Description

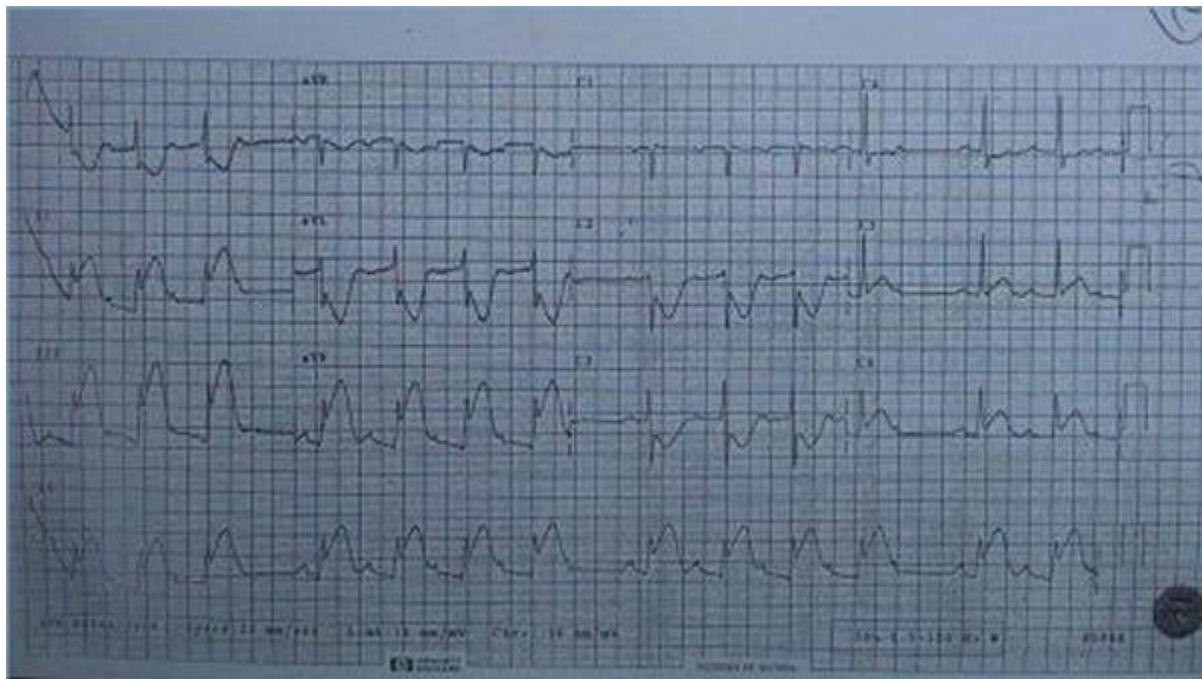
The upper rhythm strip demonstrates a VPC (yellow circle) occurring on top of the T wave of the preceding QRS complex. It probably recurs after the second QRS complex, as polymorphic VT ensues which varies both in the height and width of the complexes.

Midway through the lower rhythm strip, the VT terminates and reverts to a narrow complex rhythm that does not have an obviously prolonged QT segment (See below). At the point that the polymorphic VT terminates (blue circle) there is no evidence of a large voltage spike, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of MgSO₄.

ECG – Case 8

Question:

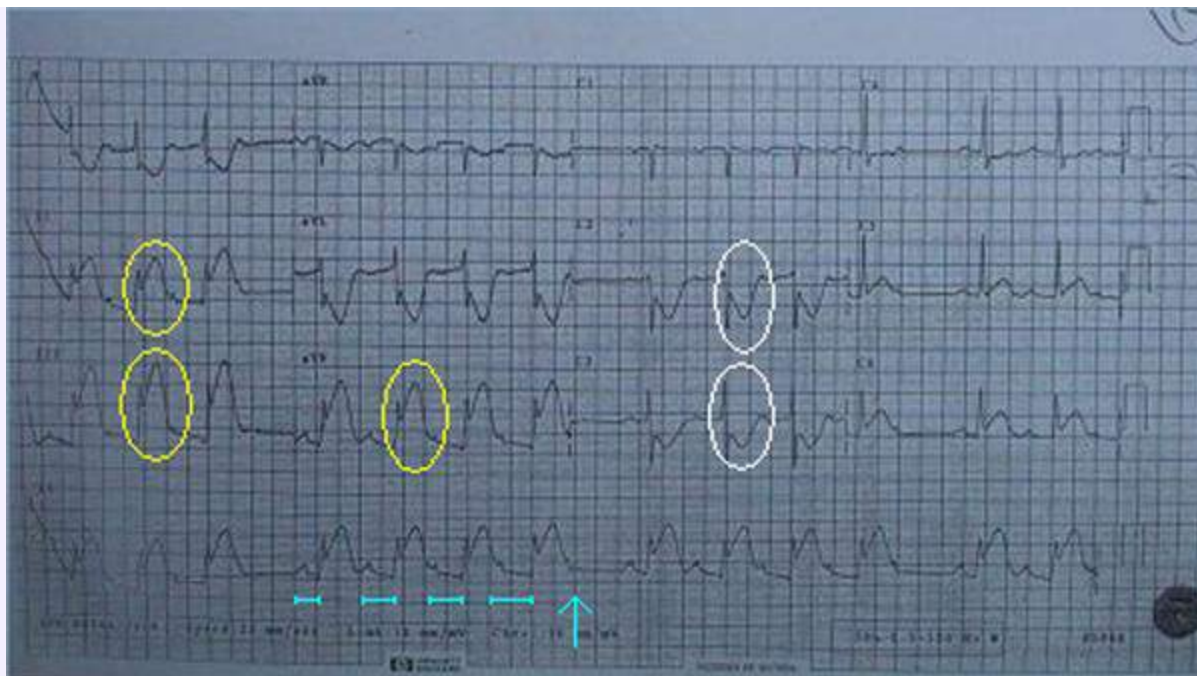
What pathologies are demonstrated on this ECG? What ECGs would you perform next?



Answer:

Pathologies = Inferoposterior acute myocardial infarction with Mobitz type I block (Wenkebach phenomenon)

The next ECGs: A right ventricular lead ECG, to exclude an RV infarct and a 15 lead ECG to confirm the presence of a posterior AMI.



Description

Significant ST elevation with hyperacute T waves in the inferior leads (II, III and aVF; yellow ellipses)

ST depression with inverted T waves, suggestive of a posterior AMI, in leads V2 and V3 (white ellipses)

The rhythm strip demonstrates a PR segment that lengthens progressively (blue bars) until a P wave fails to conduct through to the ventricles (blue arrow). This cycle repeats at a regular interval; in this case, every 5th P wave fails to conduct.

Remember, any inferior ischaemic event should prompt a search for:

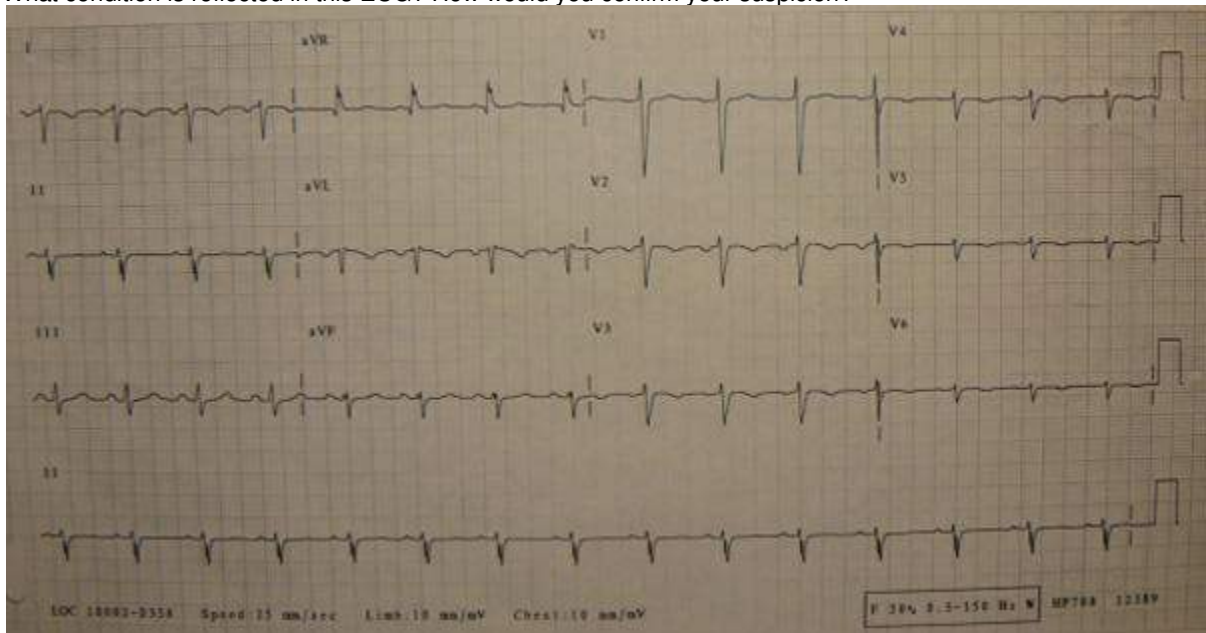
- A heart block – in this case there is a 1st degree heart block
- A right ventricular AMI, especially if the ST elevation in lead II is higher than lead III, by performing a right ventricular ECG where V1 – V6, or just V4 alone, are placed in a mirror image position to their usual place on the chest and labelled V1R – V6R. The V4R to V6R leads demonstrate a similar appearance to a lateral AMI, but as they lie over the right ventricle, reflect an RV infarct.
- A posterior AMI – flip the ECG over and bottom edge up and the waveform will look like a typical ST elevation AMI, or, perform a 15 lead ECG where leads V7 to V9 continue around from V6 to the posterior aspect of the chest.

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- ECG – Case 9

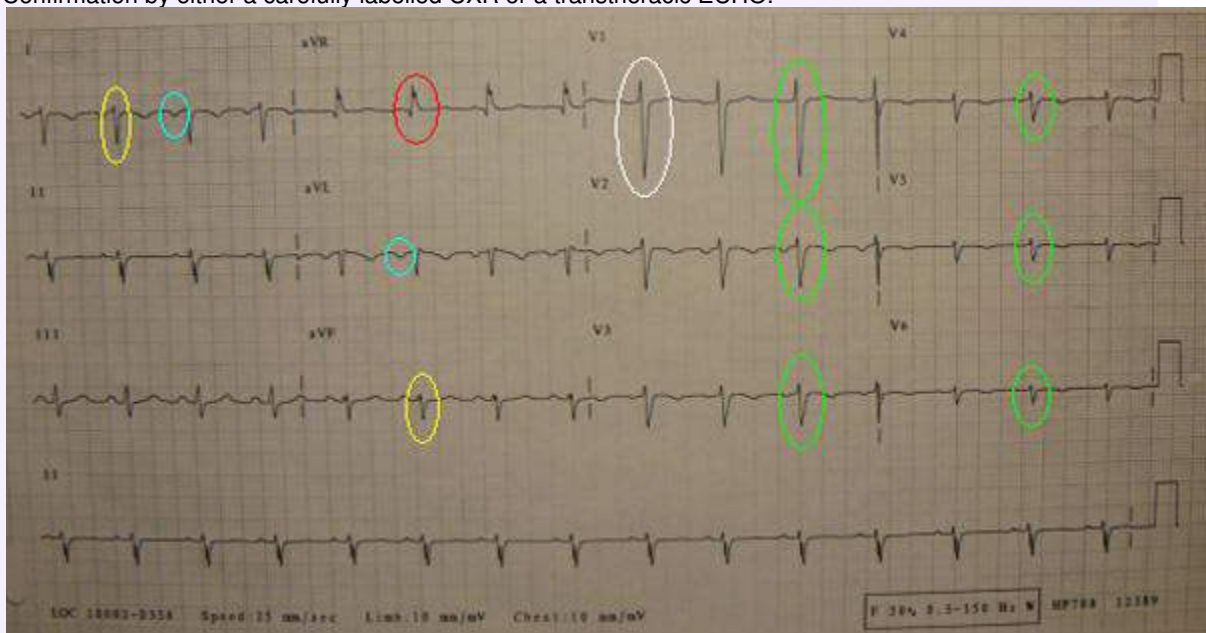
- **Question:**

- What condition is reflected in this ECG? How would you confirm your suspicion?



- **Answer:**

- Diagnosis = Dextrocardia
- Confirmation by either a carefully labelled CXR or a transthoracic ECHO.



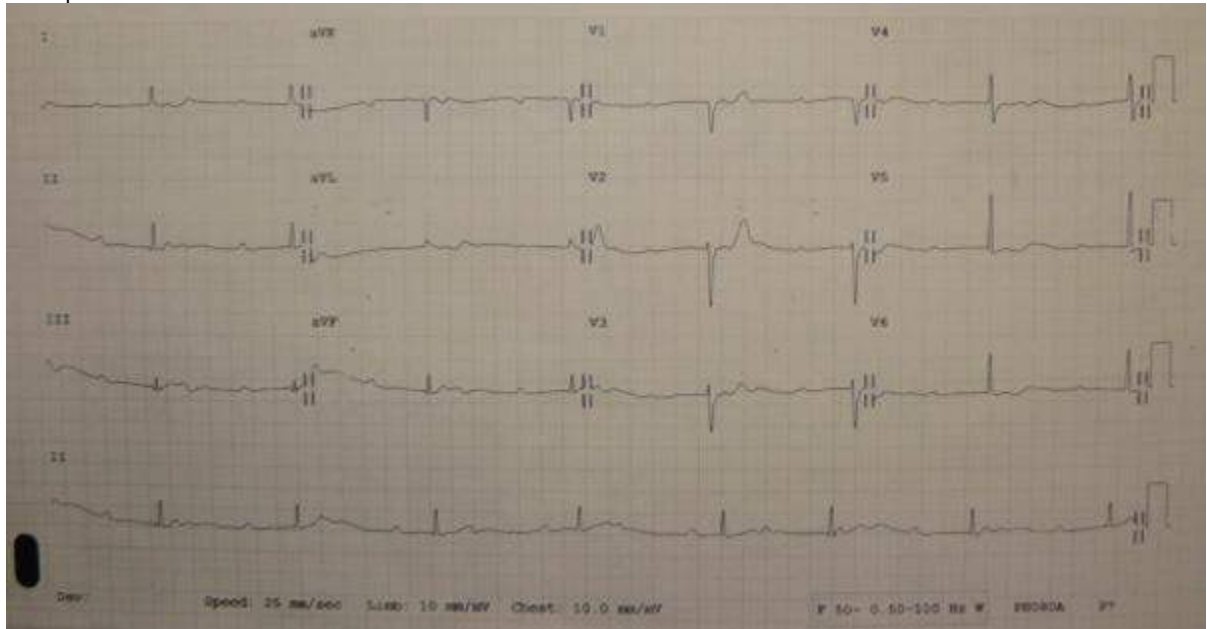
- **Description**

- Extreme right axis (yellow ellipses)
- Negative deflection P waves in leads I and aVL (blue ellipses)
- QRS in aVR (red ellipse) looks like a normal aVL complex
- Presence of an RV1 (white ellipse)
- Poor R wave progression from V1 to V6

- **ECG – Case 10**

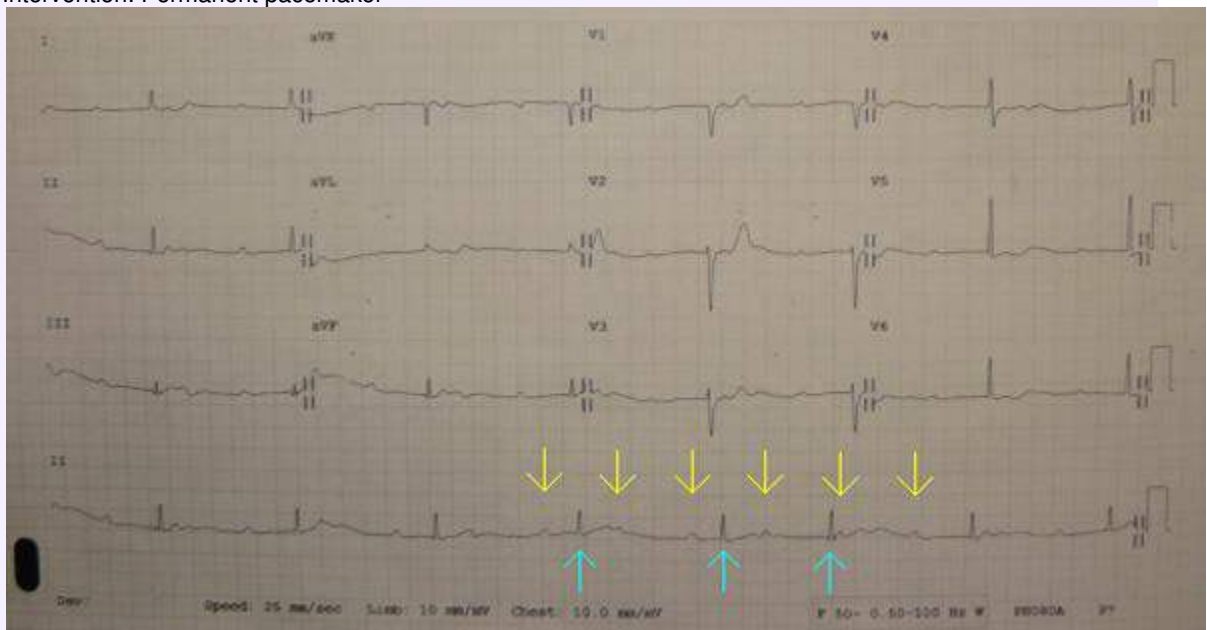
- **Question:**

- What physiological disturbance might you expect as a result of this ECG? What definitive intervention may be required?



- **Answer:**

- Diagnosis = Complete heart block
- Physiological disturbance: Hypotension
- Intervention: Permanent pacemaker



- **Description**

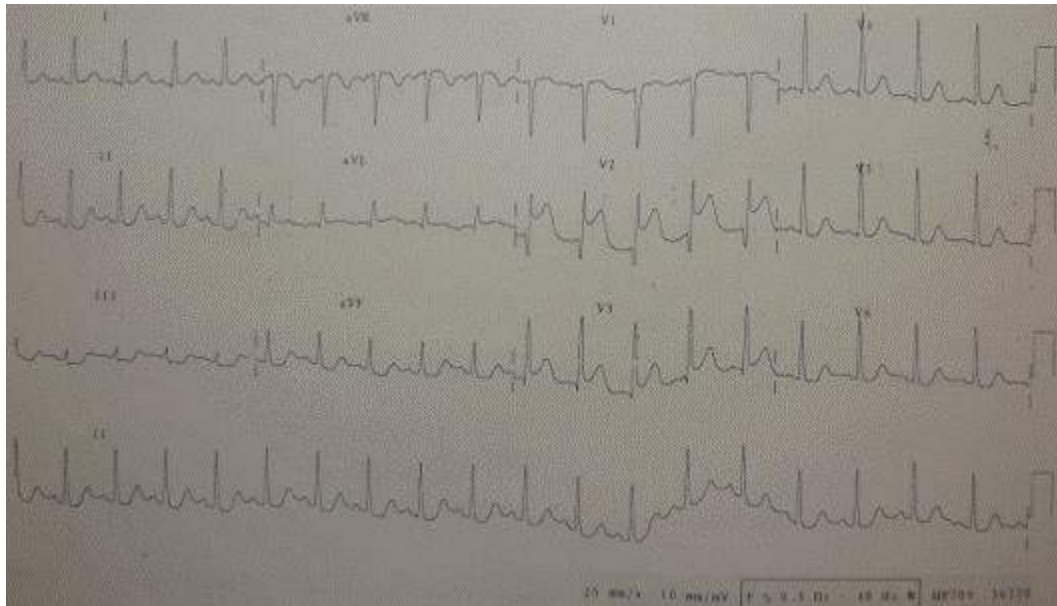
- Normal morphology P waves occurring at a regular interval (yellow arrows) and independent of the occurrence of QRS complexes (blue arrows)
- The ventricular rate is approximately 50bpm and is probably junctional in origin (narrow complex)

- No evidence of an inferior ischaemic event on this ECG (Always look for this when you identify a heart block pattern!)

ECG – Case 11

Question:

Outline your management of a patient who develops the following ECG.



Answer:

Diagnosis = Anteroseptal AMI with reciprocal changes in the inferior leads

Management:

1. Resuscitation as required
 - support oxygenation and ventilation
 - support blood pressure with IV fluid and, if necessary, an inotrope such as adrenalin

Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.

Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)

Analgesia – sublingual nitrate, IV morphine

IV heparin for a minimum of 48 hours, aiming for an aPTT of 60 - 90s

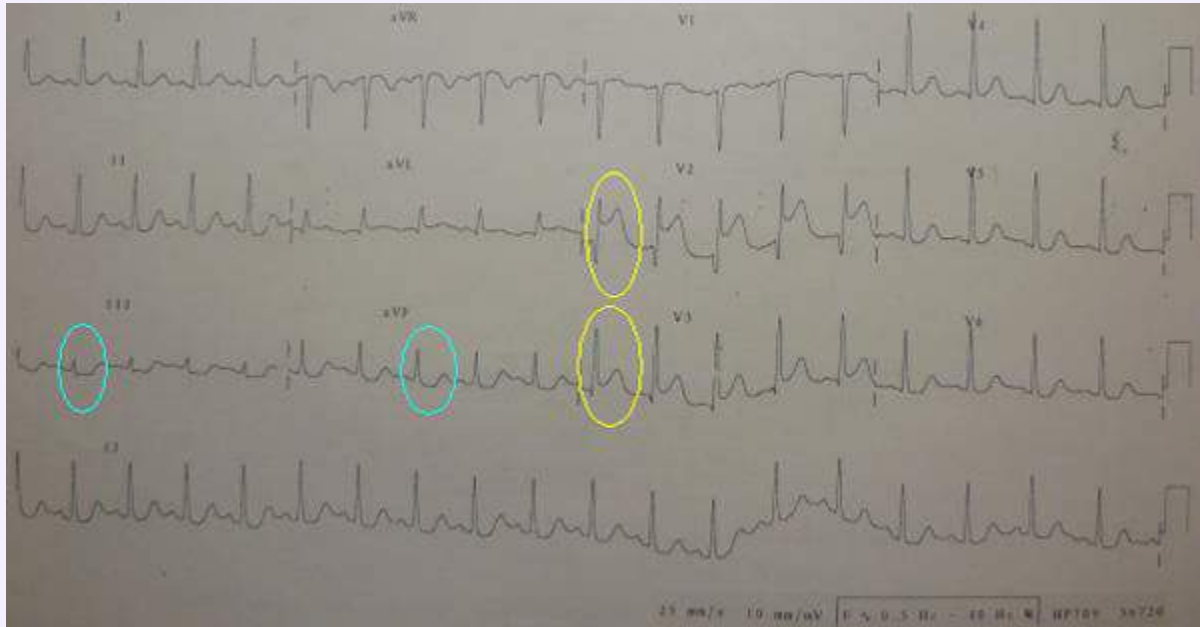
β -blockade aiming for a HR of 60 – 90bpm

Screen for remediable risk factors

Monitor for complications of an AMI, especially heart failure in this context.

Start a myocardial remodeller, e.g. ACE inhibitor or carvedilol, once that patient is stable.

Rationale:



Description

Significant ST segment elevation with hyperacute T waves in V2 and V3 (yellow ellipses) and ST depression in leads III and aVF.

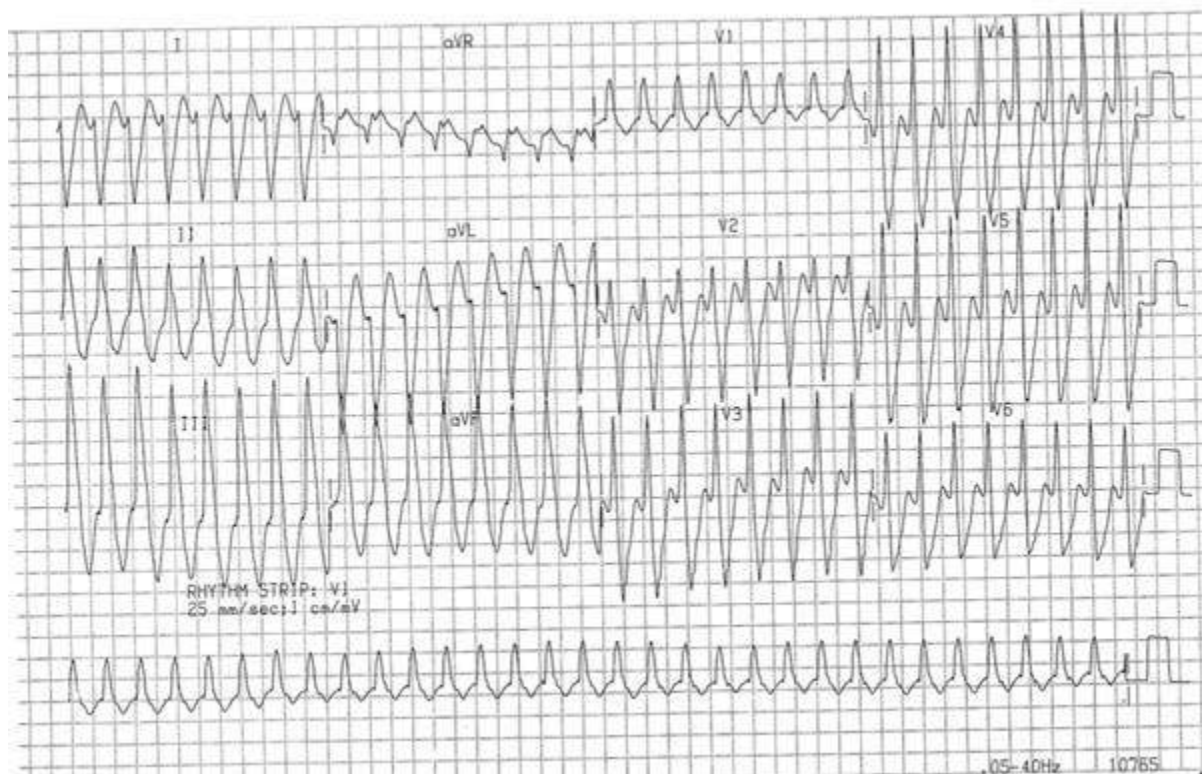
This pattern suggests an LAD lesion, which is likely to be proximal.

The lateral region is unaffected, suggesting that the circumflex has been spared and therefore the left main artery is not involved.

ECG – Case 12

Question:

What ECG features would you use to determine the source of this tachyarrhythmia?



Answer:

Diagnosis = Broad complex tachyarrhythmia, likely to be an SVT with aberrant conduction.

Features used to differentiate between a VT and an SVT with aberrant conduction

VT

- Concordance – i.e. all of the QRS complexes point in the same direction, either positive or negative
- Fusion beats – an atrial impulse is conducted successfully through to the ventricle and merges with a VT wave, producing a complex with a bizarre broad morphology
- Capture beats - an atrial impulse is conducted successfully through to the ventricle, resulting in the appearance of a normal P-QRS complex amidst the VT activity
- AV dissociation – P waves may be visible intermittently, but are not conducted effectively
- Leftward axis
- QRS > 140ms (3½ small boxes)

SVT with aberrance

1. Essentially the opposite of VT, although the QRS duration may be similarly prolonged, particularly if there is a pre-existing or rate-related BBB
2. If the broad complex tachyarrhythmia is irregular, then the decision is between VF (no output) and AF with aberrancy (may be hypotensive)

Description

A regular, broad complex tachyarrhythmia at approximately 160bpm

Right axis, possibly due to a rate-related BBB, consistent with an SVT with aberrancy

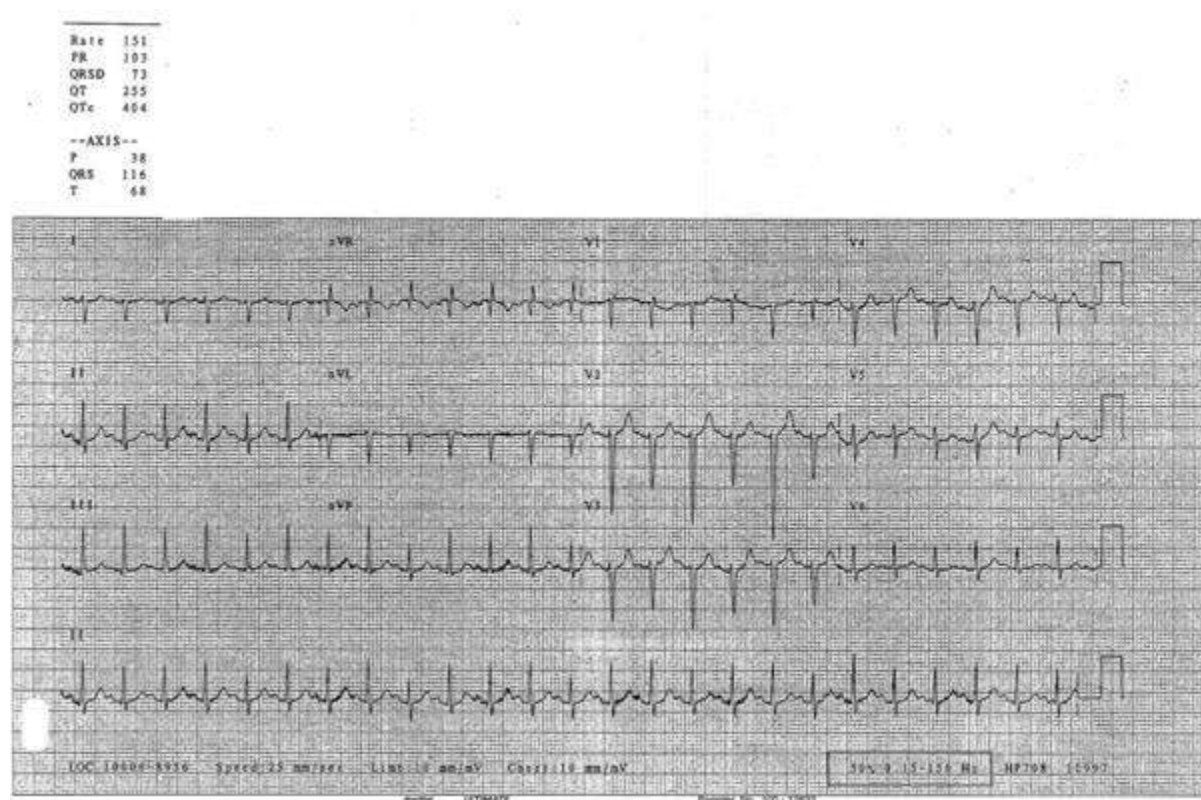
No visible P-waves, fusion beats or capture beats

Absence of a visible P-wave suggests an AVNRT

ECG – Case 13

Question:

How would you confirm the diagnosis? What therapeutic intervention would you consider for a hypotensive patient with the following ECG?

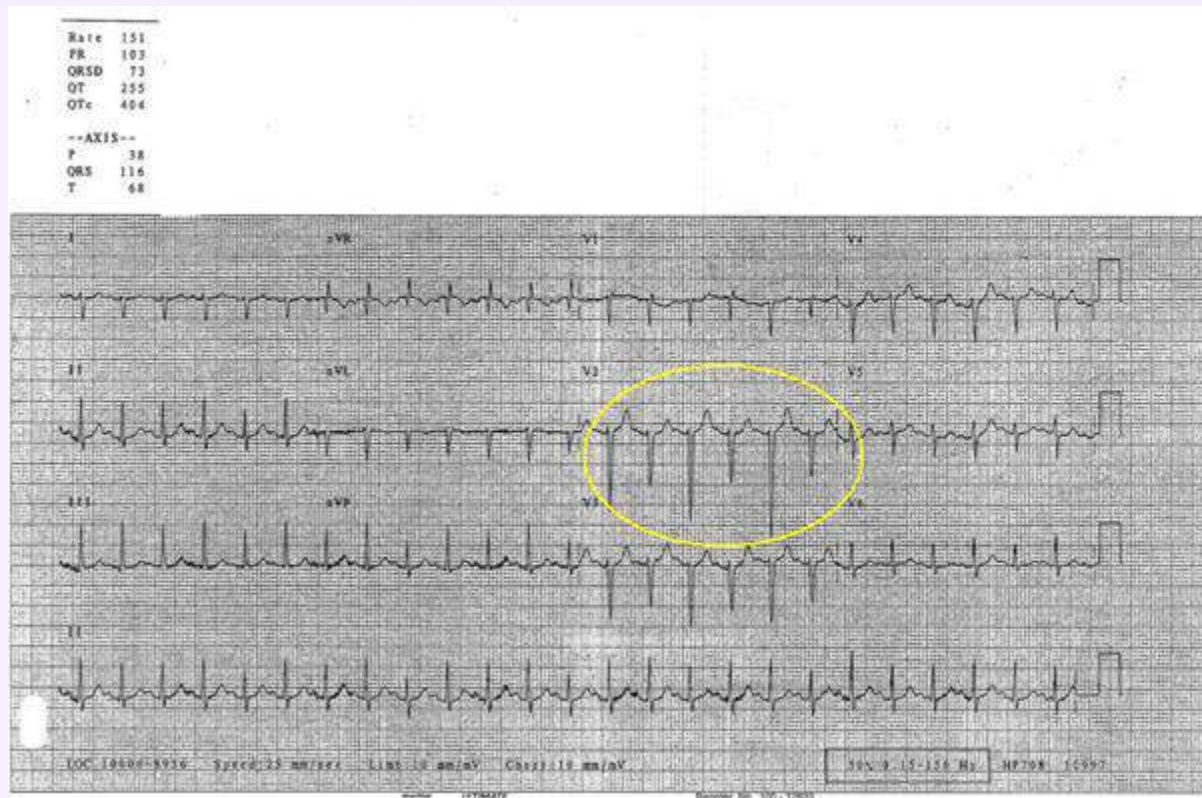


Answer:

Diagnosis = Electrical alternans, pathognomonic of a pericardial effusion

Confirmatory investigation: Transthoracic ECHO

Therapeutic intervention: Pericardiocentesis. If recurrent, a pericardial window may be required.



Description

Sinus tachycardia at approximately 150bpm with a rightward axis

Electrical alternans is demonstrated most clearly in leads V3 (yellow ellipse) and V4

The PR and QT segments are of normal duration

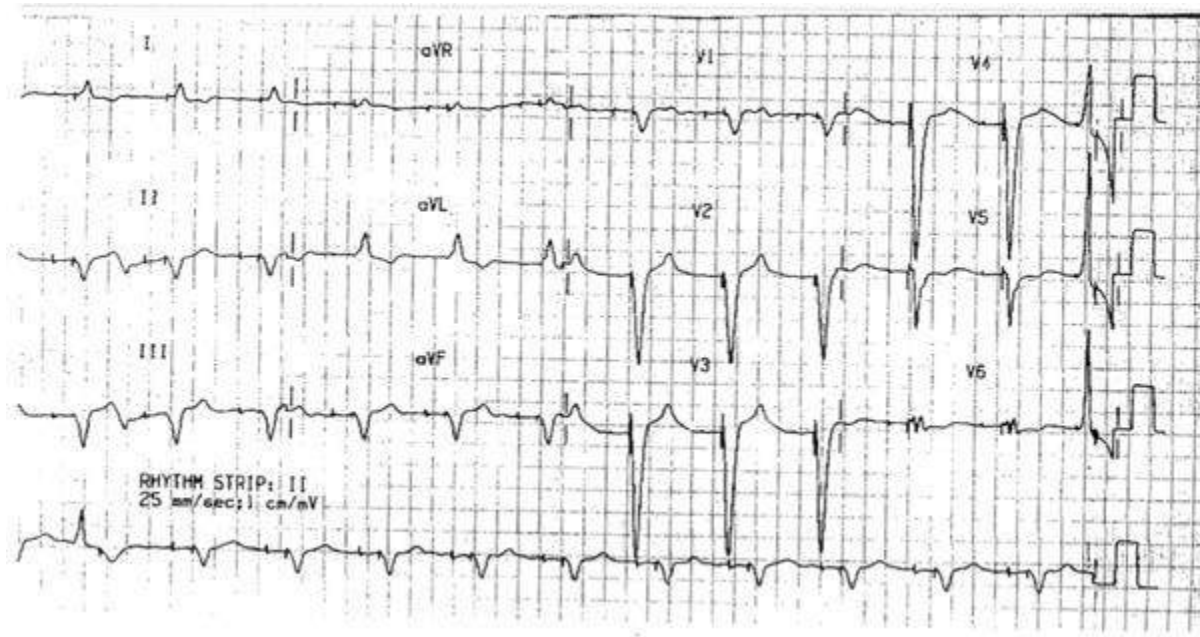
The QRS is narrow and of normal morphology

There are no ischaemic features

ECG – Case 14

Question:

List 6 causes of the following ECG abnormality.



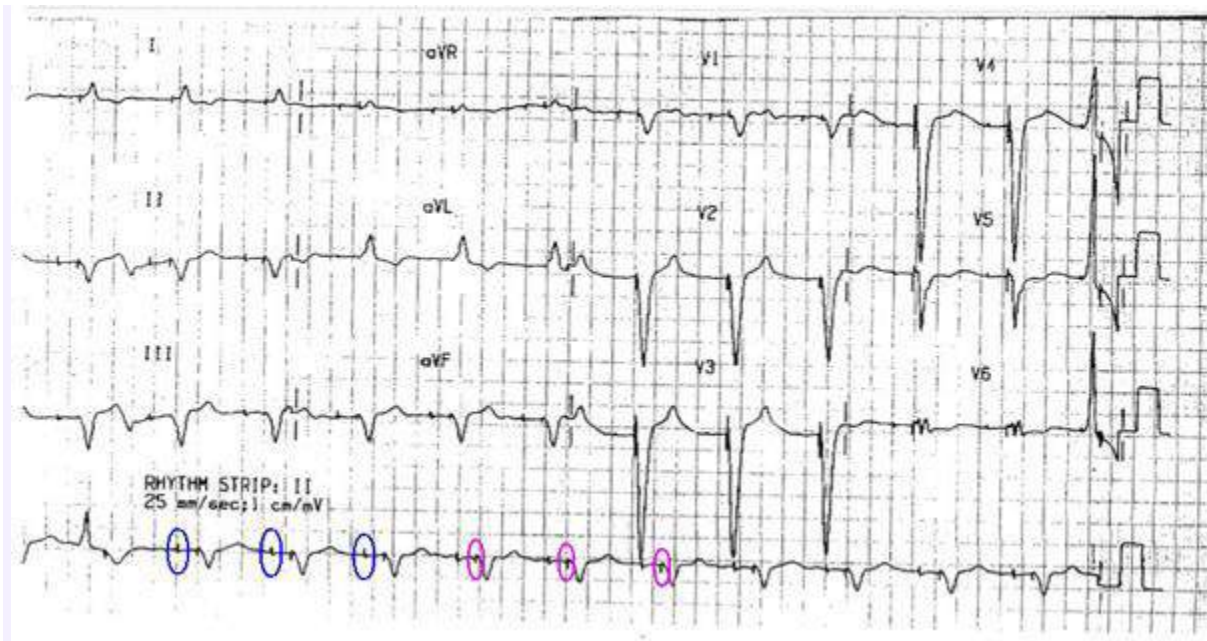
Answer:

Diagnosis = Failure of atrial lead capture in a dual lead pacemaker

Causes:

- Physiological failure – Pacemaker discharge occurs during the myocardial refractory period. (Resolved by reprogramming the pulse generator.)
- lead fracture
- fibrosis at the lead tip
- hyperkalaemia
- hypoxaemia
- myocardial ischaemia

Also consider antiarrhythmic drug toxicity.



Description

Atrial pacing spikes (Blue ellipses) which do not result in a visible atrial impulse.

There are ventricular pacing spikes (Pink ellipses) consistently followed by a broad QRS complex, suggesting that the ventricular pacing wire is functioning properly.

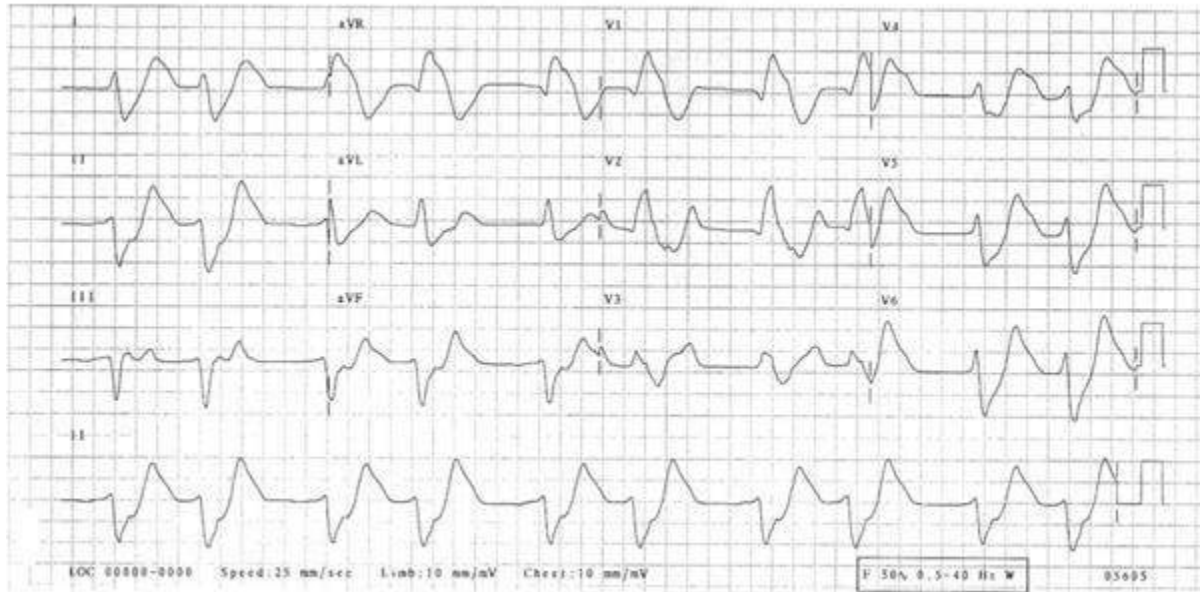
The pacemaker rate is approximately 80bpm.

There is a leftward axis, typical of a right ventricular pacing wire

ECG – Case 15

Question:

List the therapeutic interventions, along with an indication of time to effect and the mode of effect, for a patient with the following ECG



Answer:

Diagnosis = Hyperkalaemia

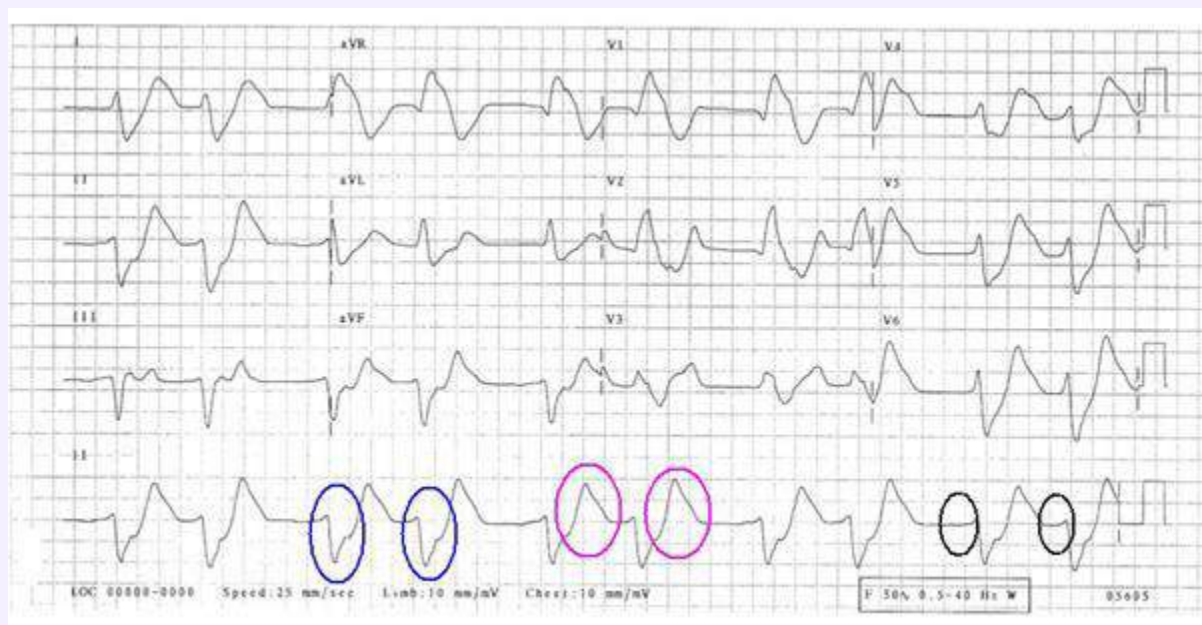
Therapeutic strategies

Therapy	Time to effect	Mode of effect
Calcium chloride 10mls 10%	Seconds to minutes	Stabilises myocardium from effect of hyperkalaemia. Avoid if digoxin toxicity suspected
0.5 – 1mEq/kg NaHCO ₃ 8.4% IV	Several minutes	Intracellular K ⁺ shift
50mls 50% Dextrose + 10U Actrapid	20 – 40 minutes	Intracellular K ⁺ shift

<p>insulin IV</p> <p>(Arguably, if the person is not a diabetic, the dextrose challenge should stimulate sufficient native insulin to achieve the desired effect)</p>		
<p>Continuous nebulised salbutamol</p>	<p>20 – 40 minutes</p>	<p>Intracellular K⁺ shift.</p> <p>(Better efficacy in paediatric population than adults)</p>
<p>Loop diuretic; e.g. frusemide 40 – 120mg IV with IV fluids to cover for the diuresis.</p>	<p>30 – 120 minutes</p>	<p>Enhanced renal excretion of K⁺ (Potassium losing diuretic)</p>
<p>Polystyrene sulfonate salt; e.g. calcium or sodium resonium 30 – 45g</p>	<p>1 – 3 hours</p>	<p>Ion exchange resin that bind K⁺ and enhances GI elimination</p>

PO/PR		
Dialysis; K ⁺ free IHD, SLED, CRRT or peritoneal dialysis	Applied for several hours, but rapidity of effect related to blood flow rate	Transfilter, or transperitoneal, K ⁺ removal

Rationale:



Description

Bradyarrhythmia with a rate of approximately 60 – 65bpm

Absent / Flat P-waves (Black ellipses)

Broad QRS complexes with bizarre morphology (Blue ellipses)

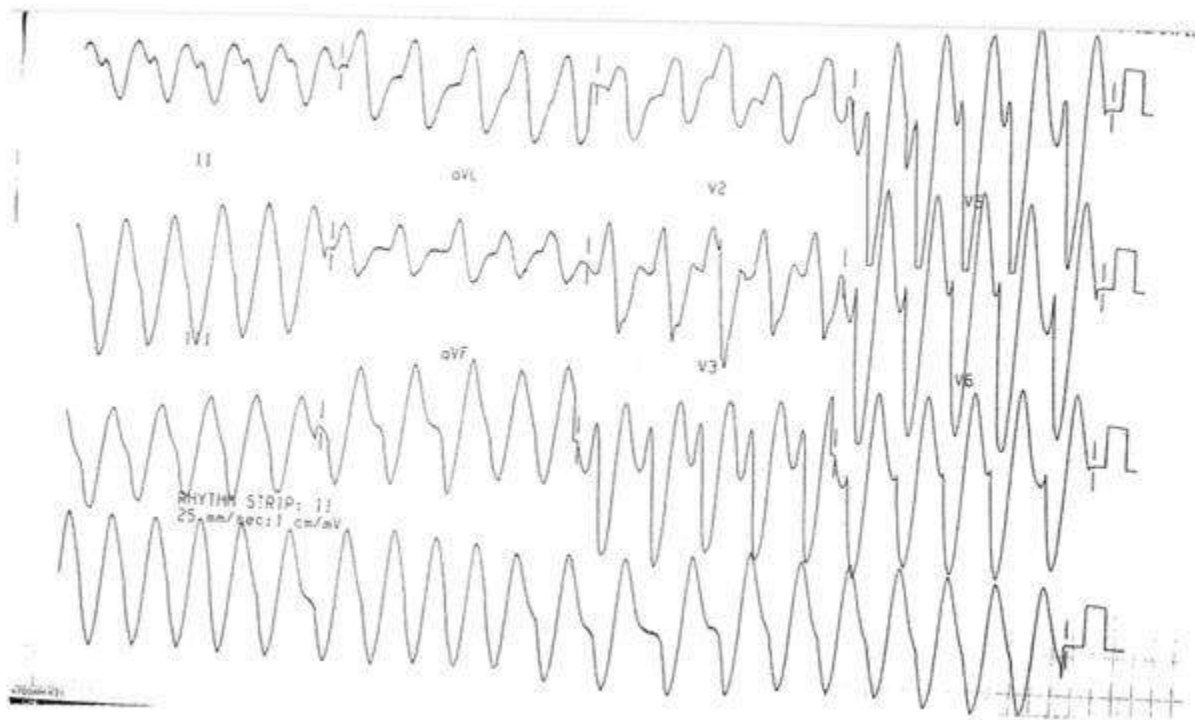
Tall, peaked T-waves (Pink ellipses)

Approaching sinusoidal waveform, which is a pre-asystolic rhythm

ECG – Case 16

Question:

A patient with a history of hypertension, depression and gout presents to the emergency department. Outline your management of the condition responsible for the following ECG.

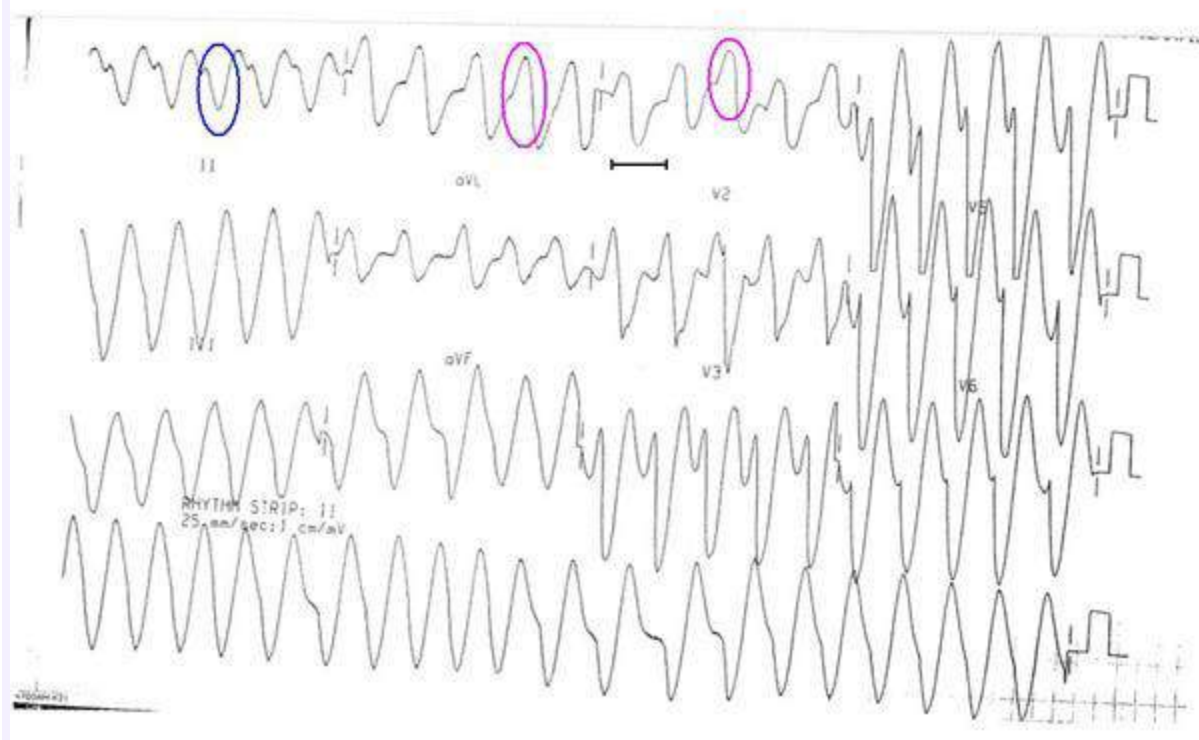


Answer:

Diagnosis = Tricyclic antidepressant toxicity

Management

1. Support oxygenation and ventilation
2. Support blood pressure with IV crystalloid. If significant hypotension, 1 – 2mEq/kg NaHCO_3 is indicated. If refractory, use noradrenalin IV infusion.
3. Treat arrhythmias (high risk if QRS >0.1s) with 1 – 2mEq/K NaHCO_3 IV, 1mg/kg Lignocaine IV and synchronised cardioversion.
4. Treat seizures (high risk if QRS >0.1s) with benzodiazepines. The role of phenytoin is controversial and not recommended by some authors.
5. 1 – 2mEq/K NaHCO_3 IV rapidly narrows the QRS complex width and reduces the risk of arrhythmias
6. Once the airway is secured, consider gastric lavage as the antimuscarinic effect often results in delayed gastric emptying and absorption of further drug can therefore be reduced
7. Consider using 20% intralipid IV, as TCADs are lipophilic
8. Full monitoring while QRS remains prolonged
9. If intentional, will require psychiatric review, once acute toxicity has resolved



Description

Broad complex, regular tachycardia

Prolonged QT interval (Black bar)

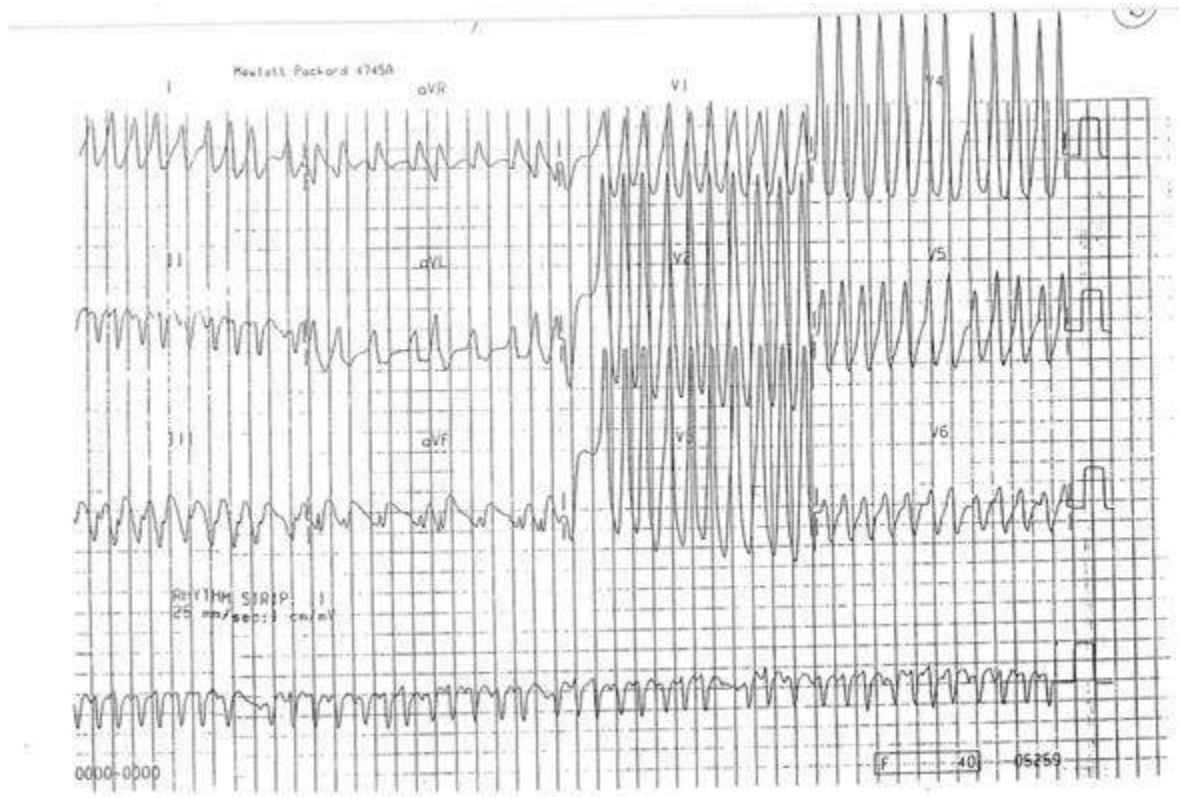
Deep S-wave in lead I (Blue ellipse)

Prominent R-wave in aVR or V1 (Pink ellipse)

ECG – Case 17

Question:

What are the treatment options for a normotensive patient with this ECG?



Answer:

Diagnosis = Wolff-Parkinson-White syndrome in atrial fibrillation with ultrarapid ventricular response

Treatment options:

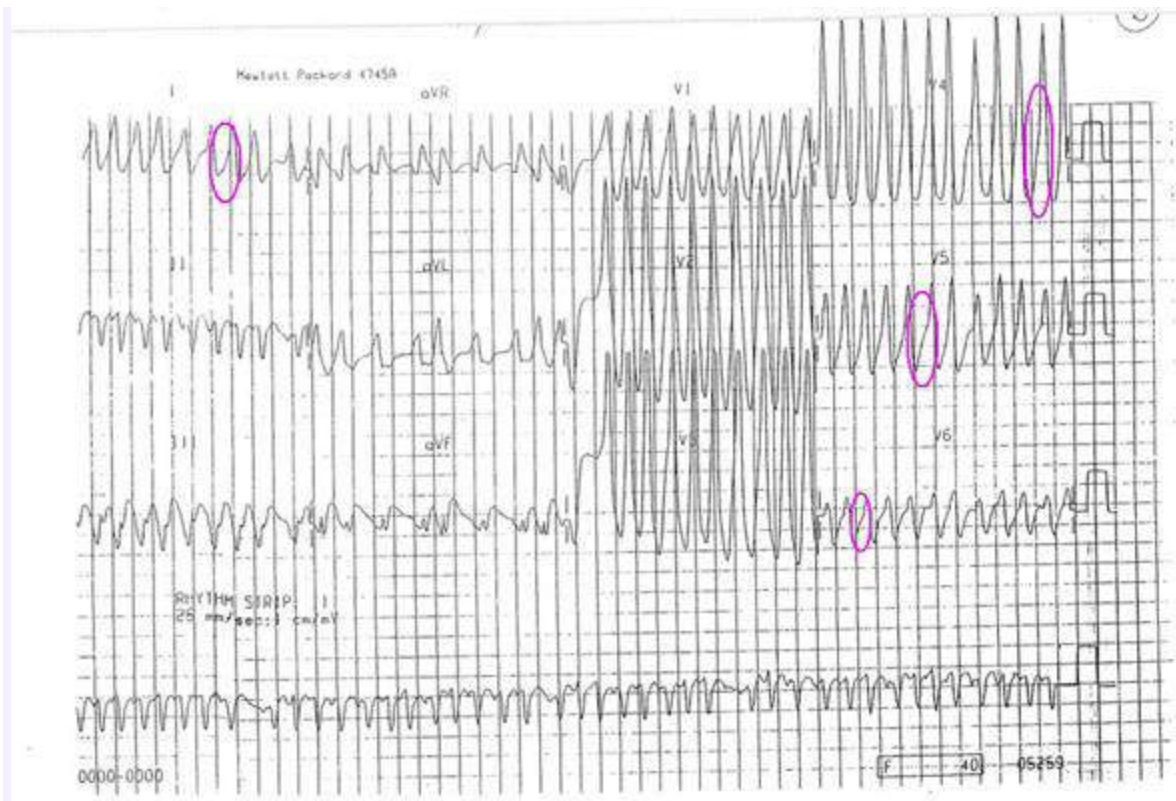
Pharmacological

1. Amiodarone
2. Procainamide
3. Flecainide

Electrical

1. Synchronised cardioversion

Avoid AV node blockers (verapamil, digoxin and β -blockers) which may accelerate the tachyarrhythmia



Description

Irregular tachycardia at approximately 300bpm

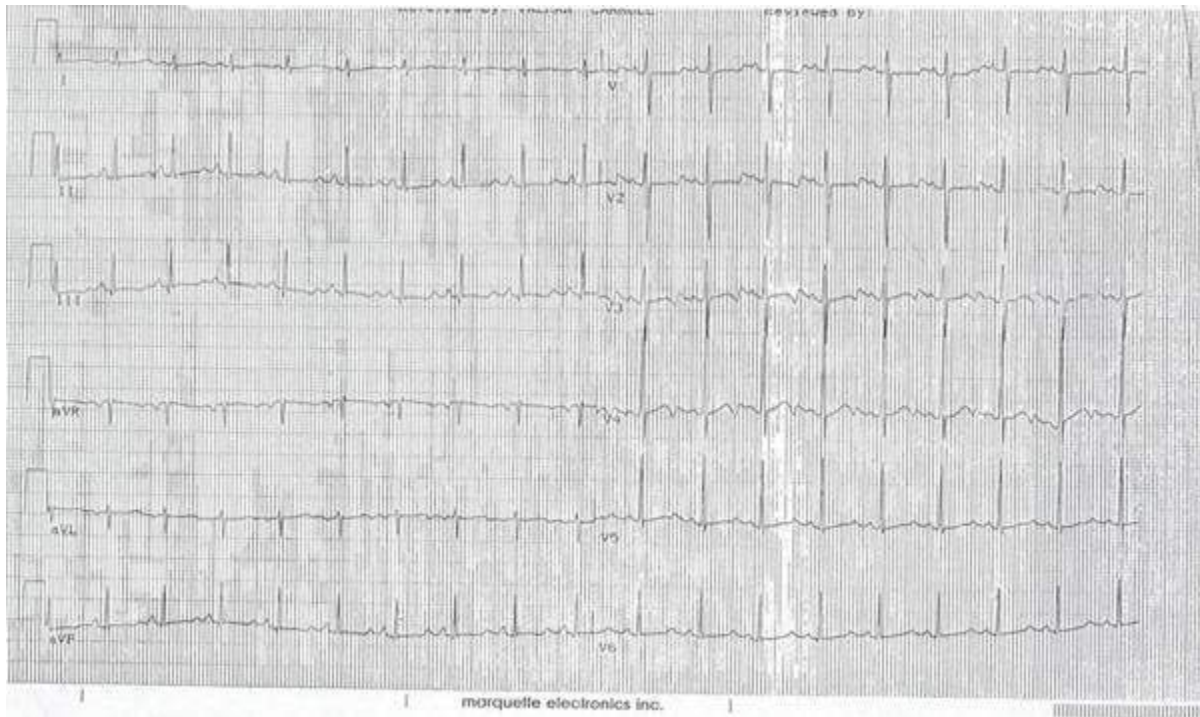
Slurred upstroke at the start of the QRS complex visible in several leads (Pink ellipses)

Difficult to determine the type (A-E) and therefore the location of the accessory tract, due to the rapidity of the tachycardia on this ECG. Obtaining a repeat ECG after the rate has been slowed would help

ECG – Case 18

Question:

List 7 causes of the following ECG appearance.



Answer:

- Electrolyte disturbances – hypoMg, hypoK, hypoCa
- Medication – Class Ia, Ic and III antiarrhythmics, macrolides, azole antifungals, antipsychotics, antidepressants, antihistamines
- Endocrinopathies – hypothyroidism, pheochromocytoma
- Cardiac disease – AMI, myocarditis
- Intracranial pathologies – ICH, CVA
- TPN
- Congenital conditions – Romano-Ward syndrome, Jervelle-Lang-Nielson syndrome



Description

If numerical data is available at the top of the ECG, one of the few to be taken on faith is the QTc, as it is tricky to calculate Bazett's formula under exam conditions. The normal QTc is < 440mSec. Alternatively, visually checking to see if the QT interval (Pink bar) appears to occupy more than half of the R-R interval (Blue bar) is a valid estimate of prolongation

Laboratory data case

These questions can provoke significant anxiety for candidates, especially for those of us who feel intimidated by maths. However, if practiced, these questions can be answered quickly, yielding valuable points and creating extra time for answering less cut and dry questions. In reality, there are only a few regularly used calculations and many cases follow common patterns that can be recognised once you have seen them a few times.

For anyone wishing to practice these types of questions, some good resources include:

- Mark Finnis' Biochemistry data set - http://www.icuadelaide.com.au/ss_finnis_notes.html
- "Data Interpretation in Critical Care Medicine"; Bala Venkatesh, T.J. Morgan, Chris Joyce; Elsevier
- "Practical intensive care medicine: *Problem solving in the ICU*." Charlie Corke. Butterworth-Heinemann, 2nd Ed.
- Crit-IQ - <http://www.crit-iq.com.au>.
- PACT (Patient-centred Acute Care Training) - The European Society of Intensive Care Medicine eLearning program, available at <http://www.esicm.org/>. Click on the "Education" tab and choose "PACT Programme" from the drop down menu.

Additionally, MRCP preparation books and online sources are fairly plentiful, although less tailored towards the ICU exam format.

Tips for the laboratory data questions

1. Read the lead-in scenario carefully. Every word is carefully placed in the stem; not to trap you, but rather to guide you towards a limited differential list. Often you can get a feeling from the stem for what diagnosis the subsequent numbers are going to result in.
2. Don't provide long-winded explanations in your answers. Succinct bullet points will buy you some time and gain you the same marks, along with a degree of credit with the examiner who has to wade through thirty or so scripts. (Note: In the cases that follow, a fuller answer than might be required by a question in the exam is provided, in order to explain the thought processes that derive the answer.)
3. Try to quantify deficits; e.g. mild, moderate, severe, life threatening. It suggests clarity and your ability to prioritise; both important consultant qualities.
4. Some of the calculations used have several variations; e.g. calculated osmolality, anion gap, corrected Na^+ in hyperglycaemia. Use whichever one you are most comfortable with.
5. If an extra value seems to have appeared amongst otherwise routine data (e.g. iCa^{2+} , uric acid, WBC differential), question why it is there, as it is unlikely to be extraneous.

Useful calculations

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO})$. Normal 6-15 mmol/L
- $\text{Corrected Na} = \text{Na} + (\text{Glucose}/3)$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Acid-base corrections:

Acid-base disorder	Rule (kPa)	Rule (mmHg) *
Primary Acute respiratory acidosis	HCO_3^- increase 1 mmol/L per 1.3 kPa rise in PaCO_2 above 5 kPa (up to 30 mmol/L)	HCO_3^- increases 1 mmol/L per 10 mmHg rise in PaCO_2 above 40 mmHg (up to 30 mmol/L)
Primary Chronic respiratory acidosis	HCO_3^- increases 4 mmol/L per 1.3 kPa rise in PaCO_2 above 5 kPa (up to 36 mmol/L)	HCO_3^- increases 4 mmol/L per 10 mmHg rise in PaCO_2 above 40 mmHg (up to 36 mmol/L)
Primary Acute respiratory alkalosis	HCO_3^- decreases 2 mmol/L per 1.3 kPa fall in PaCO_2 below 5 kPa	HCO_3^- decreases 2 mmol/L per 10 mmHg fall in PaCO_2 below 40 mmHg
Chronic respiratory alkalosis	HCO_3^- decreases 5 mmol/L per 1.3 kPa fall in PaCO_2 below 5 kPa	HCO_3^- decreases 5 mmol/L per 10 mmHg fall in PaCO_2 below 40 mmHg
Primary metabolic acidosis	$\text{PaCO}_2 \text{ (kPa)} = 0.2(\text{HCO}_3^-) + 1$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.	$\text{PaCO}_2 = (1.5 \times \text{HCO}_3^-) + 8$ PaCO_2 should be within 5 mmHg of the number denoted after the decimal point in the pH (down to a PaCO_2 10) e.g. pH 7.10 – PaCO_2 should be 10 Alternatively, expected $\text{PaCO}_2 = (\text{HCO}_3^- \times 1.5) + 8$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis.

		If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.
Primary metabolic alkalosis	$\text{PaCO}_2 \text{ (kPa)} = 0.12(\text{HCO}_3) + 1.2$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.	$\text{PaCO}_2 = (0.9 \times \text{HCO}_3) + 9$ PaCO_2 should be within 5mmHg of the number denoted after the decimal point in the pH (up to a PaCO_2 60) e.g. pH 7.6 – PaCO_2 should be 60 Alternatively, expected $\text{PaCO}_2 = (\text{HCO}_3 \times 0.9) + 9$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.

You should try and memorise some of the more common reference ranges for laboratory data, mostly as it saves time when attempting the answer. However, it is recognised that hospitals often have varying reference ranges, based on the equipment calibration, so "normal" values are usually provided in exams. A set of reference ranges is provided for the laboratory values used in the following questions. Click on reference ranges if you need a reminder.

Lab data – Case 1

Question:

A 59 year old lady on the ward has recently been treated for painful active rheumatoid arthritis. While awaiting completion of her discharge planning, a MET call is put out for a witnessed collapse that occurred when she got up to use the bathroom. The first intravenous volume bolus has not improved her blood pressure. What therapy would you consider next?

Urea 11.2mmol/L	Ca 2.37mmol/L
Creatinine 91µmol/L	Mg 0.87mmol/L
Na 127mmol/L	PO4 1.01mmol/L
K 5.9mmol/L	
Cl 96mmol/L	Albumin 36g/L
TCO2 21mmol/L	

BSL 4.1mmol/L	
Serum Osm 273mOsm/L	
Urine Osm 315mOsm/L	
Urine Na 47mmol/L	
Urine Cl 21mmol/L	

Answer:

Therapy: 100mg Hydrocortisone IV or 4mg Dexamethasone IV and then reinstate a regular oral dose of prednisone. Using dexamethasone will not preclude performing a short synacthen test.

Rationale:

Diagnosis: Addisonism secondary to acute steroid withdrawal

Recent steroid therapy is implied by management of active painful rheumatoid arthritis. The postural hypotensive episode and the blood pressure not responding as expected to a volume challenge is consistent with adrenal insufficiency, as is the hypoosmolar hyponatremia with elevated K, urine Na > 20mmol/L, low blood glucose and normal anion gap metabolic acidosis, using the TCO₂ as a surrogate for HCO₃ .

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 2

Question:

A 22 year old construction worker, who was admitted to the ward two days ago for management of an oblique left tibio-fibular shaft fracture, has been requiring increasing doses of opiate analgesia, despite immobilisation of the injured limb, and today was noted to have a reduced urine output. Outline your initial management.

Urea 24.5 mmol/L	Ca 2.03 mmol/L
Creatinine 266 µmol/L	Mg 0.98 mmol/L
Na 137mmol/L	PO4 1.33 mmol/L
K 6.0 mmol/L	Albumin 39 g/L
Cl 105 mmol/L	
TCO2 20 mmol/L	CK 43,000 U/L
BSL 8.3 mmol/L	Bilirubin 9µmol/L
	AST 246 U/L
	ALT 89 U/L
	GGT 43U/L
	ALP 82 U/L
	LDH 603 U/L

Answer:

Therapy:

- IV hydration with a crystalloid, aiming for a urine output of 1.5 – 2 ml/kg/hr
- Urinary alkalinisation with 0.5mEq/kg NaHCO₃ in 1000mls 0.9% saline, or 1mEq/kg NaHCO₃ in 1000mls 5% dextrose, at 100mls/hr, targeting a urinary pH of greater than 7.0
- The use of diuretics and mannitol to enhance elimination is controversial due to the potential for intravascular volume depletion and an enhanced risk of renal failure.
- Dialysis may be required if acute renal failure ensues, particularly with the hyperkalaemia
- If the limb has been immobilised with a full cast, split the cast to release any pressure due to swelling of the injured limb
- Advocate for theatre to perform a fasciotomy and debridement of any necrotic muscle
- Analgesia

Rationale:

Diagnosis: Rhabdomyolysis due to compartment syndrome

Predisposing injury for compartment syndrome with pain out of proportion to the apparent injury. Acute renal failure, likely due to myoglobinuria, as the raised CK and LDH suggests muscle cell destruction. Myolysis is also suggested by the raised K⁺, PO₄, Mg²⁺ and AST. The low Ca²⁺ is due to sequestration by the damaged tissue, but is rarely clinically significant and can be used as a marker for recovery.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 3

Question:

A 48 year old gentleman is brought to the emergency department via ambulance. He was found in park land, confused. His observations are as follows: HR 107bpm, BP 98/56mmHg, RR 26bpm, SpO₂ 94% RA, Temp 35.6C. What further test would you request?

Urea 11.8mmol/L	Ca 2.05mmol/L
Creatinine 109 µmol/L	Mg 0.72mmol/L
Na 129mmol/L	PO ₄ 1.35mmol/L
K 5.6mmol/L	Albumin 31g/L
Cl 86mmol/L	Uric acid 0.52 mmol/L
TCO ₂ 16mmol/L	
BSL 4.3mmol/L	
Serum Osm 298mOsm/kg	
Urine Osm 387mOsm/kg	
Urine Na 8mmol/L	

Answer:

Test requested: Serum ethanol and methanol level

Rationale:

Diagnosis: Alcohol toxicity

Young to middle aged adult found with an altered level of consciousness in a park usually suggests trauma or toxicology. A hyperosmolar hyponatraemia with a wide osmolar gap and acute renal impairment due to pre-renal deficit is consistent with alcohol toxicity. The raised anion gap metabolic acidosis is due to products of alcohol metabolism and acute renal failure. Hypoglycaemia may be an acute alcohol effect, or, in addition with the low albumin, may reflect malnutrition due to chronic alcoholism.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

-

• Lab data – Case 4

• Question:

- A 53 year old obese gentleman, with a past medical history that includes ischaemic heart disease, and hypertension, presents to the emergency department with confusion and is combative. He is afebrile, with the following observations: HR 113bpm, sinus, BP 108/74mmHg, RR 28bpm, SpO2 96% RA. What is the diagnosis and what therapy would you initiate?

Urea 16.2mmol/L	Serum Osm 352 mOsm/kg
Creatinine 118 $\mu\text{mol/L}$	Urine Osm 476 mOsm/kg
Na 146 mmol/L	Urine Na 32 mmol/L
K 3.8 mmol/L	
Cl 115 mmol/L	Ca 2.56 mmol/L
TCO2 20 mmol/L	Mg 0.76 mmol/L
BSL 36.9 mmol/L	PO4 1.53 mmol/L
	Albumin 48 g/L

-

• Answer:

- Diagnosis: Hyperosmolar hypernatraemic non-ketotic state (HHNS / HONK)
- Therapy:
 - IV rehydration with crystalloid, often requiring an 8 – 10 litre replacement over the next 48 – 72 hours. The onset of HHNS is often subacute, so correction of the deficit should mirror this. Otherwise a rapid fall in the serum Na^+ may result in cerebral oedema.
 - IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts

- K⁺ replacement may be required with the insulin infusion
- Search for and treat the precipitant; commonly sepsis, an acute coronary syndrome or a cerebrovascular event.
- These patients are at higher risk of thromboembolic events, due to the hyperosmolarity, and should receive anticoagulant prophylaxis unless contraindicated.
-
- **Rationale:**
- An obese patient in his 50's with cardiovascular risk factors with a blood glucose that is very high. HHNS hyperglycaemia is often higher than DKA hyperglycaemia. The corrected sodium is high. Don't be put off by the mild metabolic acidosis that is often present. The deranged observations and raised albumin are a reflection of the extreme dehydration, as these patients often have a volume deficit of the order of 8 to 10 litres
- Calc Osm = (2xNa) + Urea + Glucose
- Osmolar Gap = Measured Osm – Calc Osm; normal < 10mOsm/kg
- AG = (Na) - (Cl + HCO₃ or TCO₂). Normal 6-15mmol/L
- Corrected Na = Na + (Glucose/3)
- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 5

Question:

A 34 year old lady, who was admitted with a fever, altered behaviour and a rapid decrease in level of consciousness necessitating invasive airway support, has been noted to have a urine output consistently greater than 150mls/hr. A lumbar puncture is performed and the result, along with her biochemistry is displayed below. What is her diagnosis?

Urea 13.3mmol/L	<u>Lumbar puncture</u>
Creatinine 125µmol/L	Microscopy
Na 152mmol/L	RBC 3 x 10 ⁹ /ml
K 3.8mmol/L	Polymorph 32 x 10 ⁹ /ml
Cl 118mmol/L	Mono 10 x 10 ⁹ /ml
TCO ₂ 23mmol/L	No organisms seen
	Glucose 4.4mmol/L (2.5 – 5.5mmol/L)
Serum Osm 319mOsm/kg	Protein 0.78g/L (0.15 – 0.45g/L)
Urine Osm 236mOsm/kg	

Urine Na 74mmol/L	Cryptococcal Atg negative
Ca 2.41mmol/L	
Mg 0.96mmol/L	
PO4 1.10mmol/L	
Albumin 44g/L	
BSL 6.2mmol/L	
Uric acid 0.61 mmol/L	

Answer:

Diagnosis: Cranial diabetes insipidus secondary to viral encephalitis

Rationale:

Fever with altered behaviour and a rapid decline in conscious level is suggestive of an infective encephalitis, usually viral. The LP biochemistry (raised protein with relatively preserved serum to CSF glucose ratio) and cell count are supportive and a viral PCR should be requested.

A hyperosmolar hypernatraemia with inappropriately hypoosmolar urine is typical of diabetes insipidus. The setting of an intracranial pathology directs you to cranial DI. Additionally, an elevated serum uric acid also supports cranial over nephrogenic DI.

The pre-renal urea to creatinine ratio and raised serum albumin suggest an intravascular volume deficit and is consistent with the main diagnosis

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 6

Question:

A 36yo lady is admitted to the ward with an exacerbation of her ulcerative colitis. She takes prednisone and azathioprine. She is tachycardic and hypotensive. Her blood results return as follows and the team junior medical officer has requested assistance with managing her SIADH. What would you suggest?

Urea 13.4mmol/L	Serum Osm 268mOsm/kg
Creatinine 101µmol/L	Urine Osm 423mOsm/kg
Na 122mmol/L	Urine Na 4mmol/L
K 3.6mmol/L	Ca 2.15mmol/L
Cl 92mmol/L	Mg 0.77mmol/L
TCO2 19mmol/L	PO4 0.94mmol/L
BSL 7.6mmol/L	Albumin 31g/L

Answer:

Advice:

- Resuscitate her shocked state with crystalloid
- Ongoing fluid replacement over the next 48 hours should correct her hyponatremia gently
- Treat her acute ulcerative colitis exacerbation: 5-aminosalicylate + hydrocortisone or prednisone ± azathioprine

Rationale:

Diagnosis: Extra-renal sodium loss, likely secondary to GI loss due to the patient's exacerbation of ulcerative colitis

Her haemodynamic status suggests a volume deficit, which when combined with her biochemistry, produces a hypovolaemic, hypoosmolar hyponatraemia with avid renal Na retention. This is not consistent with a picture of SIADH. The admission reason suggests that there is significant diarrhoea, which is the most likely source of her extra-renal Na loss. There is a normal AG metabolic acidosis in the presence of hypokalaemia, consistent with GI bicarbonate loss

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L

- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 7

Question:

A 45 year old gentleman is brought to the emergency with increasing dyspnoea. His family have noted that his behaviour recently has been unusual and admit that he is prone to episodic alcohol binges. On examination, he is tachypnoeic and has a distended abdomen.

What is the likely diagnosis and how would you grade it?

Urea 4.1mmol/L	FiO2 28%
Creatinine 72µmol/L	pH 7.46
Na 129mmol/L	PCO2 34mmHg / 4.53 kPa
K 2.9mmol/L	PO2 88mmHg / 11.73kPa
Cl 92mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 6.4mmol/L	Hb 93g/dL
	MCV 107fl (normal 78-101 fl)
Ca 1.85mmol/L	MCH 27pg (normal 25-35 pg/cell)
Mg 0.68mmol/L	WBC 8.1x10 ⁹ /L
PO4 0.75mmol/L	PLT 105x10 ⁹ /L
Albumin 26g/L	
	aPTT 39s
Bilirubin 6µmol/L	PT 22s
AST 33U/L	INR1.5
ALT 42U/L	

GGT 57U/L

ALP 94U/L

Serum Osm 270mOsm/kg

Urine Osm 224mOsm/kg

Urine Na 7mmol/L

How would you interpret the results of the abdominal paracentesis and how do they affect your choice of therapy?

Ascitic fluid

Glucose 2.3 mmol/L

Albumin 54 g/L

pH 7.32

WBC 577 x10⁹/ml

Polymorphs 444 x10⁹/ml

RBC 89 x10⁹/ml

Gram stain: Polymorphs ++

Culture: Pure growth of Enterobacter species

Answer:

Diagnosis: Hepatic encephalopathy due to spontaneous bacterial peritonitis on a background of alcoholic cirrhosis, Childs-Pugh Grade B. The identification of an enterobacter species, an ESCAPM organism, narrows the available choice of antibiotics to gentamicin or a carbapenem.

Rationale:

A history of alcoholism. The distended abdomen is probably ascites. Hypoosmolar hyponatraemia with a low urea (which suggests he is not hypovolaemic nor in renal failure and has a decreased liver synthetic function), plus low K

(due to the impaired aldosterone metabolism), low albumen and prolonged PT and INR (due to impaired liver synthetic function). The serum and urine osmolarities also suggest he is not hypovolaemic and would not be consistent with an SIADH, thus favouring a hypervolaemic hypoosmolar hyponatraemia, such as cirrhosis. The respiratory alkalosis and mild A-a gradient would be consistent with limited diaphragmatic movement and basal atelectasis due to ascites or a metabolic encephalopathy. The LFTs need not be grossly disturbed, especially if there is little functional hepatic tissue remaining.

ESCAPM agents are identified by the presence of the Amp-C gene, which codes for an inducible β -lactamase that results in apparent in vitro sensitivity, but inevitable in vivo β -lactam resistance.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal $6-15 \text{ mmol/L}$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Child's-Pugh grading			
Score	1	2	3
Bilirubin ($\mu\text{mol/L}$)	<34	34-51	>51
Albumen (g/L)	>35	28-35	<28
PT (+ secs)	1-3	3-6	>6
Ascites	0	Grade I	Grade II
Encephalopathy	0	1-2	3-4
(West-Haven grade)			

5-6 = Child-Pugh A ® Too early for liver transplant referral

7-9 = Child-Pugh B ® Discuss with transplant team

10-15 = Child-Pugh C ® Refer to transplant team for assessment

Lab data – Case 8

Question:

A 78 year old gentleman is on SIMV with PEEP = 10 and Pmean = 18mmHg, for lobar pneumonia. He is on $0.06 \mu\text{g/kg/min}$ of noradrenalin to maintain a MAP of 65mmHg. His urine output averages 40ml/hr. The nurse is concerned about the hyponatraemia. What is causing it?

Urea 7.6 mmol/L	Bilirubin $9 \mu\text{mol/L}$
---------------------------	-------------------------------

Creatinine 71 μ mol/L	AST 39 U/L
Na 123mmol/L	ALT 36 U/L
K 4.2mmol/L	GGT 62 U/L
Cl 89mmol/L	ALP 101 U/L
TCO2 23mmol/L	
BSL 7.3mmol/L	Serum Osm 275mOsm/kg
Ca 2.26mmol/L	Urine Osm 461mOsm/kg
Mg 0.88mmol/L	Urine Na 39mmol/L
PO4 1.13mmol/L	
Albumin 34g/L	

Answer:

Diagnosis: SIADH

Rationale:

Hypoosmolar hyponatraemia with an inappropriately high urine osmolarity for the low serum osmolarity and a urine Na > 20mmol/L is almost enough by itself in an exam. A normal urea and creatinine and reasonable urine output suggest he is euvolaemic. The otherwise normal EUC, BSL, LFTs and Ca²⁺ reduce the likelihood of a renal, liver or adrenal cause, as required for the diagnosis of SIADH. The noradrenaline dose is minimal. The pneumonia is the likely precipitant of the SIADH.

If there were clinical clues that the patient was hypovolaemic (e.g. dry mucous membranes, lack of tissue oedema, lack of pulmonary oedema, tachycardia, hypotension) then consider a salt wasting syndrome, cerebral or renal, which may be quite similar biochemically, but are managed very differently (fluid restriction for SIADH, fluid replacement for salt wasting syndromes)

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L

Lab data – Case 9

Question:

A 53 year old lady has been in your ICU for 13 days following resolution of community acquired pneumonia. Having undergone aggressive early goal directed therapy by the unit registrar for her initial septic shock, she has been slow to wean from invasive mechanical ventilation, due to a persistent FiO₂ and PEEP requirement, despite the resolution of her inflammatory markers several days earlier. Her observations are: HR 92bpm sinus, BP 106/73 (no vasopressor), RR 28bpm, SpO₂ 95%, Temp 36.7°C, Urine output 60 – 120ml/hr. The nurse is concerned about the ongoing need for potassium replacement. What is the likely cause?

Urea 12.7mmol/L	pH 7.47
Creatinine 99µmol/L	PCO ₂ 46mmHg / 6.13 kPa
Na 124mmol/L	PO ₂ 92mmHg / 12.27 kPa
K 3.1mmol/L	HCO ₃ 29mmol/L
Cl 88mmol/L	SBE +3
TCO ₂ 32mmol/L	
BSL 8.3mmol/L	
Serum Osm 273mOsm/kg	
Urine Osm 325mOsm/kg	
Urine Na 34mmol/L	

Answer:

Diagnosis: Potassium-losing diuretic (e.g. frusemide, which is commonly used in ICUs)

Rationale:

Hypoosmolar hyponatraemia with hypovolaemia, suggested by the upper limit of normal HR and lower limit of normal BP in the presence of a volume contraction hypokalaemic metabolic alkalosis. The urine Na > 20mmol/L suggests renal sodium loss. The differential includes a loop diuretic or a salt wasting syndrome. The eager initial volume

resuscitation of her septic shock (EGDT), along with any sepsis related non-cardiogenic pulmonary oedema, is the likely cause for the slow ventilator wean and is being treated with a loop diuretic, resulting in the above biochemistry. It is also possible that the metabolic alkalosis that has been induced by the loop diuretic is also hindering the weaning process and it could be ameliorated by some acetazolamide.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L

Lab data – Case 10

Question:

A 25 year old gentleman is admitted to your ICU heavily sedated, intubated and ventilated following a fall from construction scaffolding. He sustained rib fractures and significant head injury. He has just returned from the operating theatre, where a decompressive craniectomy was performed. What is your explanation for his initial blood picture?

Urea 7.3mmol/L	Serum Osm 334mOsm/kg
Creatinine 87µmol/L	Urine Osm 417mOsm/kg
Na 151mmol/L	Urine Na 32mmol/L
K 2.6mmol/L	
Cl 116mmol/L	Ca 2.25mmol/L
TCO2 26mmol/L	Mg 0.87mmol/L
	PO4 0.96mmol/L
BSL 8.1mmol/L	Albumin 32g/L

Answer:

Diagnosis: Recent mannitol therapy

Rationale:

A traumatic brain injury with management suggesting there have been difficulties maintaining an appropriate ICP. Hyperosmolar hyponatraemia with a widened osmolar gap $> 10 \text{mOsm/L}$, consistent with recent mannitol therapy. The hypokalaemia suggests that the sedating agent may be thiopentone

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/L}$

Lab data – Case 11

Question:

A 59 year old lady is admitted to your ICU, having had several seizures at home. She is markedly icteric and has been intubated in the emergency department. Outline your management strategy for the first 24 hours of her admission.

Urea 18.7mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.27
Na 127mmol/L	PCO2 24mmHg / 3.20 kPa
K 3.2mmol/L	PO2 116mmHg / 15.47 kPa
Cl 87mmol/L	HCO ₃ 16mmol/L
TCO2 21mmol/L	SBE -9
BSL 2.1mmol/L	Hb 86g/dL
Ca 1.99mmol/L	MCV 111fl (normal = 78-101 fl)
Mg 0.68mmol/L	MCH 102pg (normal = 25-35 pg/cell)
PO4 0.62mmol/L	WBC $12.1 \times 10^9/\text{L}$
Albumin 28g/L	PLT $117 \times 10^9/\text{L}$
Bilirubin 134µmol/L	aPTT 41s
AST 928U/L	PT 25s
ALT 342U/L	INR 1.7

GGT 257U/L

ALP 184U/L

Serum Osm 279mOsm/kg

Urine Osm 194mOsm/kg

Urine Na 13mmol/L

Answer:

Management:

- Correct the hypoglycaemia with 50% Dextrose initially and then an ongoing 5 – 10% dextrose infusion until stable normoglycaemia
- Correct any hypovolaemia or dehydration
- Advocate for an urgent upper GI endoscopy to identify bleeding ulcer disease or varices
- Start IV octreotide 50µcg bolus and then 50µcg/hr infusion
- Start IV pantoprazole 80mg bolus and then 10mg/hr infusion
- Give IV vitamin K 5mg. Give FFP also if there is evidence of active bleeding.
- Start lactulose – PR prior to the endoscopy and via the nasogastric tube afterwards.
- Exclude sepsis, including spontaneous bacterial peritonitis
- Minimise opiate and benzodiazepine use during her period of intubation in order to avoid a prolonged sedation wean.

Rationale:

Diagnosis: Alcohol-induced acute on chronic liver failure with encephalopathy, hypoglycaemia and a likely upper GI bleed

Moderate transaminitis with an AST : ALT ratio > 2, suggests an alcoholic hepatitis. The history, level of transaminitis and hyperbilirubinaemia suggest an acute process. The hypoglycaemia, hypoalbuminaemia and prolonged PT / INR suggest diminished hepatic reserve and synthetic function and an underlying chronic dysfunction, such as cirrhosis. In addition, the low creatinine relative to the urea suggests a low muscle mass and possible malnutrition. The anaemia may be acute and, with the elevated urea out of proportion to the creatinine, may be the result of an upper GI bleed, either ulcerative or variceal. It may also reflect the alcoholic background – low Hb with raised MCV. The raised anion gap metabolic acidosis could be the result of a lactic acidosis from impaired liver function, an acute pancreatitis, an alcoholic or starvation ketosis or alcohol toxicity (less likely with the normal osmolar gap).

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L

- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 12

Question:

A 37 year old lady is admitted to the maternity ward at 34 weeks gestation (G2P1) with upper abdominal discomfort and a sensation that her shoes and rings are too tight. She has not attended any ante-natal care. On examination she has a fundal height of 35cm and six beats of clonus. Her urine appears dark. Her observations are as follows, HR 102bpm sinus, BP 133/87mmHg, RR 18bpm, SpO2 100% on nasal prongs at 4L/min, Temp 37.1°C. What management conflicts do you face for this patient?

Urea 5.9mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.43
Na 132mmol/L	PCO2 32mmHg / 4.27 kPa
K 3.4mmol/L	PO2 121mmHg / 16.13 kPa
Cl 95mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 5.1mmol/L	Hb 94g/dL
Ca 2.14mmol/L	MCV 108fl (normal = 78-101 fl)
Mg 0.72mmol/L	MCH 37pg (normal = 25-35 pg/cell)
PO4 0.92mmol/L	WBC 12.3x10 ⁹ /L
Albumin 33g/L	PLT 125x10 ⁹ /L
Bilirubin 56µmol/L	aPTT 34s
AST 137U/L	PT 21s
ALT 144UI/L	INR1.4

GGT 108U/L

ALP 139U/L

Serum Osm 273mOsm/kg

Urine Osm 182mOsm/kg

Urine Na 9mmol/L

Urine protein + + +

Answer:

Conflicts:

1. The patient is demonstrating features of evolving pre-eclampsia and HELLP syndrome. However, at 34 weeks gestation, foetal lung maturity is underdeveloped and a dose of dexamethasone 24 hours prior to delivery is desirable. Providing this period without excessive risk to the mother's health is a delicate timing issue.
2. Operative intervention in the setting of an uncontrolled coagulopathy presents an increased bleeding risk. The blood products used to correct the coagulopathy have a higher than usual risk of precipitating pulmonary oedema in this population of patients.
3. Once in the ICU, there is often a conflict of interest between supporting renal perfusion with fluids and precipitating pulmonary oedema. Both are transient, but most centres give preference to preventing pulmonary oedema and accepting a period of oliguria and deranged renal biochemistry.

Rationale:

Diagnosis: Preeclampsia / HELLP syndrome

Third trimester hypertension. The tachycardia and tachypnoea may simply reflect her third trimester status. More than 3 – 4 beats of clonus indicates hypertonicity and would be suggestive of preeclampsia in combination with her elevated blood pressure, peripheral oedema (tight rings and shoes) and proteinuria (the urine protein:creatinine ration suggests a proteinuria > 200mg/24hrs). The largely hepatitic LFTs suggest that there is more than just pre-eclampsia present and, in combination with the low platelets, indicates the presence of HELLP syndrome. Therefore, the upper abdominal discomfort may represent hepatic congestion, a subcapsular haematoma or a hepatic infarct. The raised bilirubin may be due to one or both of hepatitis or haemolysis. Remember that in the third trimester a mild compensated respiratory alkalosis is normal.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$
- Normal urine protein to creatinine ratio is < 0.2

Lab data – Case 13

Question:

You are called to see a 29 year old woman, 33 weeks pregnant with a respiratory rate of 55/min. Her pregnancy has been complicated by persistent gestational nausea. She is otherwise healthy. The following pathology is available.

a) What is the likely diagnosis?

Day 1	Day 2
Urea <0.7 mmol/L	Urea <0.7 mmol/L
Creatinine 49 $\mu\text{mol/L}$	Creatinine 51 $\mu\text{mol/L}$
Na 135 mmol/L	Na 136 mmol/L
K 3.6 mmol/L	K 4.0 mmol/L
Cl 109 mmol/L	Cl 114 mmol/L
TCO ₂ 9 mmol/L	TCO ₂ 7 mmol/L
Urate 0.6 mmol/L	Osm 290 mOsm/kg
Hb 12.3 g/dL	Ca 2.35 mmol/L
WCC 15.9 $\times 10^9/\text{L}$	Mg 0.79 mmol/L
PLT 256 $\times 10^9/\text{L}$	PO ₄ 0.98 mmol/L
	Albumin 32 g/L
	Prot 73 g/L

	Bilirubin 14 µmol/L
	ALT 29 U/L
	AST 96 U/L
	GGT 34 U/L
	ALP 217 U/L
	Glucose 4.3 mmol/L
	pH 7.19
	PaCO ₂ 17 mmHg / 2.27 kPa
	PaO ₂ 124 mmHg / 16.53 kPa
	HCO ₃ 7 mmol
	SBE -19 mmol/L
	Lactate 0.69 mmol/L
	Hb 12.3 g/dL
	WCC 17.3 x10 ⁹ /L
	Plt 339 x10 ⁹ /L

b) She was subsequently treated appropriately. The following day, her morning bloods return. What complication has occurred?.

Na 135 mmol/L	Ca 2.00 mmol/L
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K 3.5 mmol/L	Mg 0.85 mmol/L
Cl 110 mmol/L	PO4 0.36 mmol/L
TCO2 17 mmol/L	Albumin 21 g/L

Answer:

a) Starvation ketosis in pregnancy.

b) Refeeding syndrome.

Rationale:

This third trimester lady should have a mild compensated respiratory alkalosis as part of normal physiology. Instead she has a profound raised AG metabolic acidosis, in the absence of lactate, drugs or renal failure. That leaves ketosis. She is not diabetic and the blood glucose does not suggest a DKA. In fact the glucose is lower than expected, as is the albumen. Assuming she is not alcohol toxic, this leaves only starvation ketosis, which may be the result of her persistent gestational nausea. The raised WBC may be normal for gestation or a stress response to her illness

The low phosphate on day three suggests the appropriate therapy that she received included a carbohydrate load, resulting in refeeding syndrome.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

• Expected PaCO_2 for metabolic acidosis: $\text{mmHg} = (\text{HCO}_3 \times 1.5) + 8$; $\text{kPa} = 0.2(\text{HCO}_3) + 1$

Lab data – Case 14

Question:

A 19 year old gentleman presents with abdominal pain and vomiting. He looks dehydrated and pale. He has no known medical history. His observations are as follows: HR 118bpm sinus, BP 104/62mmHg, RR 32bpm, SpO2 100%, Temp 37.8°C, Urine output 100 – 140ml/hr. How will you manage him initially?

Urea 17.8mmol/L	pH 7.13
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Creatinine 103µmol/L	PaCO2 15 mmHg / 1.99 kPa
Na 130 mmol/L	PaO2 124 mmHg / 16.53 kPa
K 3.0 mmol/L	HCO ₃ 7 mmol
Cl 87 mmol/L	SBE -21 mmol/L
TCO2 11 mmol/l	Lactate 4.7 mmol/L
Osm 305mOsm/kg	Hb 13.1 g/dL
Ca 2.43 mmol/L	WCC 16.3 x10 ⁹ /L
Mg 0.54 mmol/L	Plt 532 x10 ⁹ /L
PO4 1.06 mmol/L	
Albumin 43 g/L	
Bilirubin 11 µmol/L	
ALT 27 U/L	
AST 35 U/L	
GGT 28 U/L	
ALP 100U/L	
Glucose 24 mmol/L	
Lipase 68U/L	

Answer:

Management:

- IV rehydration with crystalloid, often requiring a 4 – 6 litre replacement over the next 24 – 48 hours, depending upon the rapidity of the onset of this illness.
- IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts
- K+ replacement will be required with the insulin infusion, given the total body K+ depletion evident
- Search for and treat the precipitant; commonly sepsis, trauma or drugs in a young person.

Rationale:

Diagnosis: DKA, as a first presentation of type I diabetes mellitus.

Moderate hyperglycaemia with a raised AG metabolic acidosis. The raised lactate is not enough to account for all of the AG and the deficit is made up by ketones. The patient shows evidence of hypovolaemia and dehydration clinically, yet is polyuric. The low potassium is a concern, given the level of acidosis, and suggests significant depletion of total body potassium reserves. This suggests that the patient has been unwell for some time and will need careful electrolyte management over the next 48 to 72 hours, including replacement of the magnesium.

The Hb may reflect dehydration. The WBC is non-specific and may be associated with infection as a precipitant of the DKA, or may be a stress response. The thrombocytosis is associated with acute inflammation and dehydration

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

• Expected PaCO_2 for metabolic acidosis: $\text{mmHg} = (\text{HCO}_3 \times 1.5) + 8$; $\text{kPa} = 0.2(\text{HCO}_3) + 1$

Lab data – Case 15

Question:

Your registrar has just reviewed an oncology patient who recently started chemotherapy for a large, abdominal, high grade, non-Hodgkin's lymphoma. The patient has been oliguric for several hours. What is the diagnosis?

Urea 24mmol/L	Glucose 24 mmol/L
Creatinine 239µmol/L	Lipase 89U/L
Na 150 mmol/L	Uric acid 0.49 mmol/L
K 6.4 mmol/L	
Cl 116 mmol/L	pH 7.25

TCO2 17 mmol/l	PaCO2 27 mmHg / 3.60 kPa
	PaO2 124 mmHg 16.53 kPa
Osm 327mOsm/kg	HCO ₃ 12 mmol
	SBE –15 mmol/L
Ca 1.63 mmol/L	Lactate 2.8 mmol/L
Mg 0.99 mmol/L	
PO4 1.45 mmol/L	Hb 10.1 g/dL
Albumin 43 g/L	WCC 18.6 x10 ⁹ /L
	Plt 156 x10 ⁹ /L
Bilirubin 16 µmol/L	
ALT 32 U/L	
AST 34 U/L	
GGT 43 U/L	
ALP 107U/L	
LDH 514 U/L	

Answer:

Diagnosis: Tumour lysis syndrome

Rationale:

High grade lymphomas and leukaemias with high WBC counts are at increased risk of tumour lysis syndrome, as is the first dose of chemotherapy for a large tumour load. Raised K⁺, PO4, LDH and uric acid support the diagnosis. The hyperkalaemia is in excess of that expected for the acidosis – K⁺ rises by 0.5 for every fall in pH of 0.1. The low Ca²⁺ despite a metabolic acidosis has a limited differential, including tumour lysis syndrome and rhabdomyolysis. The

widened AG is due to the release of intracellular acids from lysed cells and contributes to the hyperkalaemia and hyperuricaemia

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

• Expected PaCO_2 for metabolic acidosis: mmHg = $(\text{HCO}_3 \times 1.5) + 8$; kPa = $0.2(\text{HCO}_3) + 1$

Lab data – Case 16

Question:

Your registrar is concerned about a patient in the unit who is proving difficult to wean from ventilatory support. The patient has multiple small bowel fistulae following an open necrosectomy and several revisions for significant necrotising pancreatitis and the surgeons have requested that TPN be continued for 2 – 3 more weeks. The pancreatitis has been settled for some time and all inflammatory markers have returned to normal. Drain outputs are negligible. The patient has a tracheostomy and remains on pressure support ventilation. There are no vasopressors required and the urine output is satisfactory. The patient is receiving an insulin infusion at 12u/hr. The patient is on no antibiotic and has a clear CXR and clear urine microscopy. The observations are as follows: RR 32bpm, SpO₂ 98% (FiO₂ 0.3), HR 110bpm sinus, BP 128/76mmHg, Temp 38.3°C. You are shown the most recent blood results. What is your response?

Urea 11.3mmol/L	Glucose 15 mmol/L
Creatinine 99µmol/L	Lipase 89U/L
Na 147 mmol/L	Uric acid 0.45mmol/L
K 5.5 mmol/L	
Cl 112 mmol/L	pH 7.32
TCO ₂ 29 mmol/l	PaCO ₂ 48 mmHg / 6.39 kPa
	PaO ₂ 154 mmHg / 20.53 kPa
Osm 332.3mOsm/kg	HCO ₃ 28 mmol
	SBE +3 mmol/L
Ca 2.39mmol/L	Lactate 1.1 mmol/L
Mg 1.19 mmol/L	

PO4 1.22 mmol/L	Hb 10.1 g/dL
Albumin 28 g/L	WCC $14.3 \times 10^9/L$
	Plt $259 \times 10^9/L$
Bilirubin 18 $\mu\text{mol/L}$	
ALT 62 U/L	
AST 58U/L	
GGT 121 U/L	
ALP 126 U/L	
Triglycerides 3.01 mmol/L	
Total cholesterol 5.7 mmol/L	

Answer:

Diagnosis: Overfeeding syndrome

Response: Decrease the TPN rate and adjust the contents and proportions to meet the patient's nutritional needs appropriately.

Rationale:

The patient is in the weaning phase and the acute pathology has settled. Therefore complications of therapy must be considered when evaluating new problems. Despite a lack of active pancreatitis markers and no apparent infection source, the patient remains tachypnoeic, tachycardic and hyperthermic. This is due to the increased metabolic state from the excess nutritional supply. The excess nutrition results in hyperglycaemia, (despite being chased by a higher than usual insulin infusion rate in this patient), hyperlipidaemia, mildly deranged LFTs (hepatic steatosis from the hyperlipidaemia) and electrolyte disturbances, along with increased CO₂ production. Patients with overfeeding syndrome may also display delirium, peripheral oedema and excess weight gain.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

- Corrected Ca = Ca + 0.02(40 – albumin)
- Expected HCO₃ for respiratory acidosis: Acute - HCO₃ increases 1mmol/L per 10mmHg rise in p_aCO₂ above 40mmHg (up to 30mmol/L) ; HCO₃ increase 1mmol/L per 1.3kPa rise in p_aCO₂ above 5kPa (up to 30mmol/L)

•Expected HCO₃ for respiratory acidosis: Chronic - HCO₃ increases 4mmol/L per 10mmHg rise in p_aCO₂ above 40mmHg (up to 36mmol/L); HCO₃ increases 4mmol/L per 1.3 rise in p_aCO₂ above 5kPa (up to 36mmol/L)

Lab data – Case 17

Question:

A 56 year old gentleman is transferred from a regional hospital following a difficult intubation for repeated seizures. The intubation was made difficult by tongue swelling that occurred when the patient bit his own tongue during one of his seizures. His initial blood results return as follow:

Na 142mmol/L	Hb 6.7 g/dL
K 3.8 mmol/L	Retics 503 x 10 ⁹ /L
Cl 106 mmol/L	WBC 9.2 x 10 ⁹ /L
HCO ₃ 28mmol/L	Neut 6.5 x 10 ⁹ /L
Urea 10.6 mmol/L	Lymph 2.3 x 10 ⁹ /L
Creatinine 117 µmol/L	MCV 103fl (normal 78-101 fl)
	MCH 35 (normal 25-35 pg/cell)
Uric acid 0.35 mmol/L	MCHC 348 (normal 31 – 36 Hb/cell)
Glucose 11.7 mmol/L	RDW 28.9
	PLT 39 x 10 ⁹ /L
Bili 36 µmol/L	
ALT 13 U/L	Comment: Neutrophils show slight left shift.
AST 29 U/L	Marked polychromasia. Many fragmented red cells.
ALP 75 U/L	
GGT 17 U/L	PT 15.0 s (11.0 – 15.0s)
Alb 31 g/L	INR 1.22

Prot 57 g/L	aPTT 25.8 s (24.0 – 33.0s)
LDH 1,352 U/L	Fibrinogen 3.02 g/L (2.00 – 4.00g/L)
	D-dimer 10.86 µg/ml (<1.00)
Ca 2.03 mmol/L	
PO4 0.69 mmol/L	
Mg 0.89 mmol/L	

a) What diagnosis would you consider?

b) What specific therapy would you consider?

Answer:

Diagnosis: Thrombotic thrombocytopenic purpura

Therapy:

- Plasmapheresis – recommended first line therapy for TTP
- Immunoglobulin
- Methylprednisone

Rationale:

Seizures (neurology) + renal failure + thrombocytopenia + haemolytic anaemia (low Hb + raised reticulocytes + raised LDH + fragmented red cells on the blood film). A history of a febrile illness would complete the TTP pentad. The raised D-dimer is related to the microvascular thrombosis that is part of the pathology

Lab data – Case 18

Question:

A 37 year old lady is in the emergency department with abdominal pain. The emergency registrar is concerned enough to request you to review the blood results and tells you that she is a mildly obese woman, with swelling in the region of both angles of her jaw. Her abdomen is soft with no consistent regional tenderness. She has no known past

medical history and is not on any regular medications. Her heart rate, blood pressure, respiratory rate and oxygen saturation are normal.

Na 120 mmol/L	pH 7.51
K 2.0 mmol/L	PaCO ₂ 49 mmHg / 6.53 kPa
Cl 64 mmol/L	PaO ₂ 103 mmHg / 13.73 kPa
HCO ₃ 48 mmol/L	HCO ₃ 45mmol/L
Urea 4.2 mmol/L	SBE +13
Creatinine 67 µmol/L	SaO ₂ 99%
Glucose 5.5 mmol/L	
Bili 11 µmol/L	
ALT 20 U/L	
AST 34 U/L	
ALP 70 U/L	
GGT 19 U/L	
Alb 38 g/L	
Prot 63 g/L	
Ca 2.24 mmol/L	
PO ₄ 0.98 mmol/L	
Mg 0.85 mmol/L	

a) What diagnosis would you consider?

b) What additional features would you examine for to support your diagnosis?

Answer:

a) Diagnosis: Bulimia nervosa

b) Supportive features: Eroded fingernails, from repeated self-induced vomiting, erosion of dental enamel, especially of the incisors.

Rationale:

Mildly obese female with bilateral parotid swelling, due to repeated self-induced vomiting, and a non-specific abdominal complaint + a metabolic alkalosis which is hypokalaemic and hypochloraemic, which suggests H⁺ ion loss + a hyposmolar hyponatremia due to extra renal sodium loss.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumen})$

• Expected PaCO₂ for metabolic alkalosis: mmHg = (HCO₃ x 0.9) + 9; kPa = 0.12(HCO₃) + 1.2

Lab data – Case 19

Question:

A 31 year old lady is admitted to the ICU from theatres following a dilation and curettage for a foetal death in utero at 18 weeks gestation. She had become febrile and hypotensive over the past 24 hours, precipitating the operation. Her procedure was complicated by heavy blood loss and she received 7 units of packed red blood cells and 4 units of fresh frozen plasma. Her admission haematology is as follows:

Hb 7.6 g/dL	PT 31.9 s (11.0 – 15.0s)
WBC 20.9 x 10 ⁹ /L	INR 3.10
Neut 18.7 x 10 ⁹ /L	aPTT 85.9 s (24.0 – 33.0s)
Lymph 1.2 x 10 ⁹ /L	Fibrinogen 1.22 g/L (2.00 – 4.00g/L)
MCV 99fl (78-101 fl)	Thrombin time 22.1s (15.0 – 19.0s)
MCH 34 (25-35 pg/cell)	D-dimer 8.93 µg/ml (<1.00)

MCHC 338 (31 – 36 Hb/cell)	
RDW 15.3	
PLT $128 \times 10^9/L$	

What haematological condition would you suspect?

Answer:

Diagnosis: Disseminated intravascular coagulopathy (DIC)

Rationale:

Raised aPTT, PT, Thrombin time and D-dimer with a low fibrinogen + thrombocytopenia. The likely precipitants include a septic (febrile, hypotensive and leucocytosis) abortion and the massive blood transfusion, which has not followed a 1:1 Packed RBCs to FFP ratio, with no platelets given.

Lab data – Case 20

Question:

A 72 year old gentleman has been intubated in the emergency department for increasing work of breathing and a decline in his level of consciousness during the management of his suspected community acquired pneumonia. The nurse looking after him shows you his first blood gas following his transfer to the ICU. What measures would you take?

FiO ₂ 0.5	Hb 9.1g/dL
pH 7.49	Na 137 mmol/L
PaCO ₂ 26 mmHg	K 3.7mmol/L
PaO ₂ 101 mmHg	iCa 1.13 mmol/L
HCO ₃ 20 mmol/L	iCa (pH 7.40) 1.18mmol/L

SBE -2.8	Glucose 6.3 mmol/L
SaO2 98%	Lactate 1.1 mmol/L

Answer:

Measures to take: Check the ventilator minute ventilation, ventilator frequency and tidal volume. Usually a decrease of the frequency is all that is required. The tidal volume may need to be reduced if inappropriately high. Check that the patient is not in pain and has an appropriate level of sedation to assist tolerance of invasive ventilation. Exclude alternative pathologies, such as meningitis, encephalitis, cerebral oedema or drug toxicities (e.g. salicylate, theophylline).

Rationale:

Diagnosis: Respiratory alkalosis due to overventilation.

Raised pH with a low PaCO₂ and appropriate compensatory fall in the HCO₃ in a mechanically ventilated patient. There is also a raised Aa gradient, though this is unlikely to be driving a tachypnoea given the adequate PaO₂. There is no evidence of a co-existing metabolic acidosis to drive an increased respiratory drive.

- Expected HCO₃ for respiratory alkalosis: Acute - HCO₃ decreases 2mmol/L per 10mmHg fall in paCO₂ below 40mmHg; HCO₃ decreases 2mmol/L per 1.3 fall in paCO₂ below 5kPa
- Expected HCO₃ for respiratory alkalosis: Chronic - HCO₃ decreases 5mmol/L per 10mmHg fall in paCO₂ below 40mmHg; HCO₃ decreases 5mmol/L per 1.3kPa fall in paCO₂ below 5kPa

Lab data – Case 21

Question:

A 48 year old lady is brought to the emergency department confused and febrile, with a heart rate of 140bpm and a blood pressure of 220/97mmHg. She appears mildly cachectic. Her blood tests are presented below.

Na 144 mmol/L	Hb 11.6 g/dL
K 4.4 mmol/L	WBC 15.7 x 10 ⁹ /L
Cl 106 mmol/L	Neut 14.7 x 10 ⁹ /L

HCO ₃ 23 mmol/L	Lymph 0.5 x 10 ⁹ /L
Urea 18.3 mmol/L	MCV 84fl (normal 78-101 fl)
Creatinine 253 µmol/L	MCH 30 (normal 25-35 pg/cell)
	MCHC 34.6 (normal 31 – 36 Hb/cell)
Glucose 11.5 mmol/L	RDW 13.4
CK 562 U/L	PLT 86 x 10 ⁹ /L
Ca 2.11 mmol/L	
PO4 1.38 mmol/L	
Mg 1.10 mmol/L	
Free T4 47.8 pmol/L (10.5 – 21.2pmol/L)	
TSH 0.050 mIU/L (0.35 – 0.36mIU/L)	
Free T3 6.6 pmol/L (2.5 – 7.3pmol/L)	

What specific therapy would you suggest?

Answer:

Therapy, in order of administration:

- Decrease the systemic sensitivity of catecholamine receptors and the peripheral conversion of T4 to T3 using non-selective β-blocker: Propranolol 0.5 – 1mg IV q5min until HR less than 100bpm to maximum 10mg, then enteral propranolol 60 – 120mg q4hr until the crisis abates. Cardioselective β-blockers can be used, but are less effective. Guanethedine or reserpine are used in patients with reactive airways disease or other contraindications to β-blockers.
- Reduce thyroid hormone synthesis: Enteral propylthiouracil 1000mg loading dose, then 200 – 400 mg q4hr. Carbimazole has also been used.
- Reduce the release of preformed thyroid hormone: Lugol's iodine 8 - 10 drops q6hr enterally. Alternatively, iodinated contrast agent can be used if Lugol's iodine is not available.
- Steroids: Hydrocortisone 300 mg loading followed by 100 mg tds, as there is often a relative hypoadrenalism. It also alters the peripheral conversion of existing thyroid hormones. .

- Treat the precipitant – usually sepsis.
- Supportive therapy – fluid balance, nutritional support, avoid salicylates and frusemide which can release bound thyroid hormone, active cooling of hyperpyrexia, thiamine and sedation if agitated.

Rationale:

Diagnosis: Hyperthyroid crisis

High T4 with suppressed TSH is consistent with primary hyperthyroidism (Grave's disease, toxic multinodular goitre, acute Reidel's thyroiditis, amiodarone-induced thyroiditis). Also consistent with a thyrotoxic crisis is her clinical presentation with fever, confusion and increased heart rate and BP. Associated laboratory abnormalities include hyperglycaemia (including non-diabetics), raised WBC, raised Ca^{2+} and low K^+ and Mg^{2+}

Lab data – Case 22

Question:

A 19 year old lady has been brought to the emergency department by her friends, in a state of inebriation. She is tearful and incoherent, requiring a small dose of midazolam to calm her. Her friends state that she recently broke up with her boyfriend. What therapy would you consider based on her blood results?

Na 143 mmol/L	Hb 12.4g/dL
K 4.7 mmol/L	WBC $13.6 \times 10^9/\text{L}$
Cl 99 mmol/L	Neut $11.7 \times 10^9/\text{L}$
HCO_3^- 19 mmol/L	Lymph $1.2 \times 10^9/\text{L}$
Urea 5.9 mmol/L	MCV 90fl (normal 78-101 fl)
Creatinine 182 $\mu\text{mol/L}$	MCH 31 (normal 25-35 pg/cell)
	MCHC 33.8 (normal 31 – 36 Hb/cell)
Glucose 5.9 mmol/L	RDW 10.9
	PLT $201 \times 10^9/\text{L}$
Bili 113 $\mu\text{mol/L}$	
ALT 2029 U/L	PT 34.3 s (11.0 – 15.0s)
AST 3006 U/L	INR 3.24

ALP 39 U/L	aPTT 41.7 s (24.0 – 33.0s)
GGT 38 U/L	Fibrinogen 2.32 g/L (2.00 – 4.00g/L)
Alb 33 g/L	Thrombin time 17.6s (15.0 – 19.0s)
Prot 52 g/L	D-dimer >20.0 µg/ml (<1.00)
Ca 1.88 mmol/L	FiO2 0.3
PO4 1.84 mmol/L	pH 7.23
Mg 1.12 mmol/L	PaCO2 46 mmHg / 6.13 kPa
	PaO2 89 mmHg / 11.87 kPa
	HCO ₃ 19 mmol/L
	SBE -7.6
	SaO2 97%

Answer:

Therapy:

- Consider ventilatory support for the respiratory acidosis, as her impaired liver may not metabolise the "small dose of midazolam" effectively.
- Start N-acetylcysteine infusion.
- Vitamin K is often not given in this situation, unless there is significant bleeding, as it is used to monitor the progress of the liver failure.
- FFP is not required unless there is bleeding.
- By the King's College Hospital criteria for liver transplantation for paracetamol-induced acute liver failure, she should be referred for early consideration for liver transplantation.
- Once the acute organic illness has settled, she will require a psychiatry assessment (Don't forget about this important component of her overall management!)

Rationale:

Diagnosis: Acute liver failure due a combination of alcohol and paracetamol overdose

The mode of presentation is highly suggestive of a reactive suicide attempt and a combination of paracetamol and alcohol is the most common in young women. The LFTs suggest an acute hepatitis and a transaminitis in the thousands suggests either an ischaemic or, in this case, a toxic aetiology. The coagulopathy and raised bilirubin are consistent with liver failure and a raised INR is one of the earliest indicators of paracetamol induced liver failure. Her ABG demonstrates a mixed respiratory and raised AG metabolic acidosis, which is likely to be attributable to a lactic acidosis, secondary to her liver failure.

- $AG = (Na) - (Cl + HCO_3 \text{ or } TCO_2)$. Normal 6-15mmol/L
- Expected $PaCO_2$ for metabolic acidosis: $mmHg = (HCO_3 \times 1.5) + 8$; $kPa = 0.2(HCO_3) + 1$

King's College Hospital criteria for liver transplantation for paracetamol-induced acute liver failure.

- $pH < 7.3$, or,
- $INR > 6.5$ and Serum creatinine $> 300\mu\text{mol/L}$ and West-Haven III-IV hepatic encephalopathy

Lab data – Case 23

Question:

A short synacthen test has been performed on one of your patients who is being treated for severe respiratory sepsis. How would you interpret the result?

Na 134 mmol/L	<u>Synacthen 0.25mg</u>
K 5.7 mmol/L	Cortisol T-0 411 nmol/L
Cl 105 mmol/L	Cortisol T-30 581 nmol/L
HCO_3 23 mmol/L	
Urea 5.9 mmol/L	
Creatinine 182 $\mu\text{mol/L}$	

Answer:

Interpretation: While the renal biochemistry and failure of cortisol to rise above the 600nmol/L threshold after synacthen suggest adrenal insufficiency in the setting of severe sepsis, the implications of this on management are much debated.

The concept of relative adrenal insufficiency is not universally accepted, with concerns about validation of measurement thresholds in critical illness and the interpretation of results obtained when critical illness has altered plasma proteins and total and free cortisol fractions. Therefore, the use of stress dose steroids remains controversial. My practice is to

Rationale:

Diagnosis: The renal biochemistry and result of the short synacthen test suggests adrenal insufficiency, which is a much debated pathology associated with critical illness and severe sepsis in particular.

Hyponatraemia + hypokalaemia + normal AG metabolic acidosis. A baseline cortisol (T-0, time zero) between 100 – 550nmol/L is neither specific for adrenal insufficiency nor adequacy. However, while a rise in cortisol level to less than 600nmol/L, or by less than 250nmol/L, by 30 minutes (T-30) after synacthen administration is consistent with adrenal insufficiency in an outpatient population, its implications for a critically ill patient is still hotly debated.

Lab data – Case 24

Question:

A 20 year old male is involved in a high speed car crash arrives in ICU after having internal fixation of a femoral fracture and application of external fixation to a complex pelvic fracture. Large volumes of fluids and blood products were infused in the Emergency Department then in the operating theatre. The arterial blood gas on arrival to ICU and the electrolytes sampled around this time are available. What is the likely cause of the acidosis and why? Analyse the results using concepts from the Stewart theory.

<u>Blood gases:</u>	<u>Electrolytes:</u>
FiO2 0.5	
pH 7.28	Na 146 mmol/L
paCO2 36 mmHg / 4.79 kPa	K 3.3 mmol/L
paO2 125 mmHg / 16.67 kPa	Cl 115 mmol/L
HCO ₃ 21 mmol/L	HCO3 21 mmol/L
Lactate 1.4 mmol/L	Urea 7.9 mmol/L
	Creat 90 µmol/L

	Albumin 33 mmol/L
	Phosphate 1.8 mmol/L

Answer:

In the setting of a high chloride and the clinical context of needing large volumes of fluid and blood product resuscitation the likely cause is a hyperchloraemic acidosis.

In this case:

- $SID = 21 + (0.28 \times 33 + 2.14 \times 1.8) = 21 + 9.24 + 3.85 = 34.1$
- This is less than 42, a low SID
- $SIG = [(146 + 3.3) - (21 + 115)] - (9.24 + 3.85) = (149.3 - 136) - 13.09 = 0.2$
- This is around 0, a normal SIG

Rationale:

The equations that are of practical relevance presented as follows:

- $SID = [HCO_3^-] + A^-$ (where normal is approximately 42)
- $SIG = \text{Anion gap} - A^-$ (where normal is approximately 0)
- where $A^- = 0.28 \times \text{Albumin (g/L)} + 2.14 \times \text{Phosphate (mmol/L)}$

• $\text{Anion gap} = [Na^+ + K^+] - [HCO_3^- + Cl^-]$

Lab data – Case 25

Question:

A 38 year old lady was admitted to the ICU 7 days ago for a massive PE, which was thrombolysed successfully and remains on IV anticoagulation. She is being weaned from the ventilator, having been treated with appropriate antibiotics for an aspiration pneumonia that occurred during the original intubation. The nurse raises a concern about apparent swelling of her right upper limb and shows you her most recent blood results. What specific laboratory tests would you request?

Na 141 mmol/L	Hb 12.9g/dL
K 4.3 mmol/L	WBC $8.6 \times 10^9/L$
Cl 97 mmol/L	MCV 82fl (normal 78-101 fl)

HCO ₃ 26 mmol/L	MCH 29pg (normal 25-35 pg/cell)
Urea 6.9 mmol/L	MCHC 33.6 (31 – 36 Hb/cell)
Creatinine 89 µmol/L	PLT 56 x 10 ⁹ /L
Glucose 6.3 mmol/L	PT 14.3 s (11.0 – 15.0s)
	INR 0.9
Bili 13 µmol/L	aPTT 44.9 s (24.0 – 33.0s)
ALT 29 U/L	Fibrinogen 3.02 g/L (2.00 – 4.00g/L)
AST 30 U/L	Thrombin time 14.6s (15.0 – 19.0s)
ALP 22 U/L	D-dimer <1.0 µg/ml (<1.00)
GGT 31 U/L	
Alb 37 g/L	
Prot 58 g/L	
Ca 2.38 mmol/L	
PO4 1.02 mmol/L	
Mg 0.97 mmol/L	

Answer:

Laboratory tests:

- HIT screen for heparin-PF4 complex antibodies. Confirmation by a positive activation test, using donor platelet serotonin release, is generally not required as it is more difficult and expensive due to the need for specific donor platelets. A positive PF4 assay with resolution of the platelet count after cessation of the heparin is considered confirmatory, although false negative PF4 assays can occur.
- Lupus anticoagulant
- SLE screen: ANA, anti-dsDNA, anti smooth muscle antibody, VDRL, anticardiolipin antibody, serum complement. Lupus anticoagulant is often positive in SLE.

Rationale:

Diagnosis: HIT type 2

The combination of a raised aPTT with the occurrence of a possible venous thrombosis (the swollen right upper limb) has a limited differential – HIT, lupus anticoagulant or an intravascular device, which has probably become infected, in someone on heparin. The presence, degree and timing of the thrombocytopenia favours HIT, although SLE is still a possibility

Lab data – Case 26

Question:

A 61 year old patient has been receiving continuous renal replacement therapy in your ICU for contrast induced acute renal failure. The nurse shows you the latest set of bloods for review. What is your response?

Na 137 mmol/L	Hb 11.3g/dL
K 3.8 mmol/L	WBC $7.7 \times 10^9/L$
Cl 95 mmol/L	MCV 80fl (normal 78-101 fl)
HCO ₃ 28 mmol/L	MCH 30pg (normal 25-35 pg/cell)
Urea 15.0 mmol/L	MCHC 33.9 (31 – 36 Hb/cell)
Creatinine 219 $\mu\text{mol/L}$	PLT $156 \times 10^9/L$
Glucose 8.3 mmol/L	PT 12.6 s (11.0 – 15.0s)
Bili 10 $\mu\text{mol/L}$	INR 0.8
ALT 23 U/L	aPTT 31.0 s (24.0 – 33.0s)
AST 26 U/L	
ALP 34 U/L	
GGT 45 U/L	

Alb 33 g/L	
Prot 51 g/L	
Ca 1.58 mmol/L	
iCa 0.81mmol/L	
PO4 0.82 mmol/L	
Mg 0.57 mmol/L	

Answer:

Response: Check the pre-filter citrate infusion rate. Increase the post filter calcium infusion rate.

Rationale:

Diagnosis: Biochemical effect of citrate anticoagulated dialysis.

In general, CRRT dialysis circuits require some form of anticoagulation, in order to preserve filter life by minimising filter thrombosis. Typically this is done with heparin, which usually results in an elevation of the aPTT, even if post filter protamine is used (regional heparinisation). Alternatives include fondaparinaux, danaparoid, a hirudin analogue (eg bivalirudin, lepirudin) and citrate. There has been a resurgent interest in citrate dialysis recently and, of all of the above anticoagulant alternatives, only citrate excess results in a hypoglycemic hypomagnesaemia. The mildly raised HCO_3^- is likely to be due to the hepatic metabolism of systemic citrate

Lab data – Case 27

Question:

This 70 year old female presented with dizziness and had a history of recent syncopal episodes. On examination she had a loud ejection systolic murmur noted which radiated to her carotid arteries. An echocardiogram demonstrated severe aortic stenosis with features suggesting a calcification bicuspid valve. She was admitted for surgery and the following pre-operative blood results were noted:

WBC $5.0 \times 10^9/\text{L}$ (3.5-10)	HCT 0.16 (normal 0.35-0.40)
RBC $1.94 \times 10^9/\text{L}$ (3.8-5.1)	MCV 70 fl (normal 78-101 fl)

HGB 48 g/L (120-150)	MCH 22 pg/cell (normal 25-35 pg/cell)
----------------------	---------------------------------------

a) Interpret the results. What is the most common cause of this picture? What test will you order to confirm your suspicion?

b) The patients Iron studies were performed.

Iron 3 $\mu\text{mol/L}$ (low)

Total Iron Binding Capacity 92 $\mu\text{mol/L}$ (high)

Ferritin 6 $\mu\text{g/L}$ (low)

Do these results confirm your suspected diagnosis? What is a single unifying diagnosis that would tie together this picture and severe aortic stenosis?

Answer:

a) There is a marked microcircuit, hypochromic anaemia. The most likely cause is iron deficiency anaemia. Iron studies will be helpful.

b) Yes. The results are consistent with Iron deficiency anaemia. There are a number of potential causes of this that need investigating, but angiodysplasia is a known association with severe aortic stenosis where it is termed Heyde's Syndrome. It is thought that von Willebrand factor is proteolysed due to high shear stress from turbulent flow across the diseases aortic valve, increasing the risk of bleeding from intestinal telangiectasias that are increasingly common with advancing age.

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Lab data – Case 28

Question:

A 65-year-old man underwent a Whipple's procedure for resection of a pancreatic adenocarcinoma. An anastomotic leak and pancreatic fistula complicated this. Total parenteral nutrition was provided. After a month of TPN trace elements were ordered and the results shown:

Plasma/serum chromium 5 nmol/L (1-26 nmol/L)

Plasma/serum selenium 0.9 $\mu\text{mol/L}$ (0.9-1.4 $\mu\text{mol/L}$)

Plasma/serum zinc 2.6 $\mu\text{mol/L}$ (10-19 $\mu\text{mol/L}$)

Plasma/serum copper 14.8 $\mu\text{mol/L}$ (12-22 $\mu\text{mol/L}$)

Blood manganese 90 nmol/L (60-350 nmol/L)

Blood selenium 1.1 $\mu\text{mol/L}$ (1.2-2.1 $\mu\text{mol/L}$)

Comment on the findings.

Answer:

The results suggest a deficiency of zinc and to a lesser degree selenium.

Both trace elements are known to commonly fall in critically ill patients, including surgical patients requiring TPN. Both are important antioxidants involved in host defense against free radicals. Zinc is also involved in wound healing and glycaemic control. The risks, benefits and most appropriate regimen for replacing trace elements in the critically ill patient remains unclear although this is an area of current active research

Lab data – Case 29

Question:

A 22 year old lady has been in the ICU for management of her septic shock secondary to ascending cholangitis. Overnight, as her therapy was being weaned she received an accidental bolus of noradrenalin, resulting in a brief period of significant hypertension. Subsequently, she has been complaining of a severe headache, requiring increasing boluses of opiate analgesia. A head CT was performed the following day and has been reported as normal. A lumbar puncture is performed and you are shown the results. What is your interpretation? What investigation would you request next?

<u>CSF</u>	<u>Blood</u>
Protein 0.59g/L (0.15 – 0.45g/L)	Glucose 7.2mmol/L
Glucose 6.9mmol/L (2.5 – 5.6mmol/L)	
	Hb 12.9g/dL
Appearance: clear, xanthochromic supernatant	WBC $13.5 \times 10^9/L$
	PLT $435 \times 10^9/L$
RBC $5340 \times 10^9/ml$	
Polymorphs $8 \times 10^9/ml$	
Mono $6 \times 10^9/ml$	

Answer:

Diagnosis: Subarachnoid haemorrhage, secondary to catecholamine surge

Investigation: A CT angiogram, to look for cerebrovascular aneurysms.

Rationale:

A severe headache after a period of significant hypertension raises the possibility of an intracranial haemorrhage (SAH, intracerebral) or a carotid or vertebral artery dissection. A head CT should reliably show an intracerebral haemorrhage, but if there is a delay in performing it, a subarachnoid haemorrhage may be missed due to reduced sensitivity. However, as the sensitivity of a head CT for an SAH declines over the initial 24 hours, the sensitivity of an LP improves. The red cell to white cell ratio (>300 – 500:1) of the sample above does not support an infective aetiology

Lab data – Case 30

Question:

A 32 year old gentleman is admitted to your ICU for management of his septic shock following a right sided percutaneous nephrostomy tube insertion for obstructive ureterolithiasis which has resulted in right sided pyelonephritis. He has been commenced on empiric ceftriaxone and is on 0.7µcg/kg/min of noradrenalin. The following day a microbiology report is phoned through to the department and handed to you. What would you do next?

Urine microscopy

RBCs >100 x10⁹/ml

WBC > 100 x10⁹/ml

Epithelial < 10 x10⁹/ml

Organisms seen

Culture: Pure growth E.coli

This organism has tested positive for ESBL

Answer:

Intervention: Change the cephalosporin antibiotic to a carbapenem; e.g. meropenem, imipenem.

Rationale:

ESBL organisms, typically gram negative enterobacteriaceae such as E.coli and klebsiella, have a plasmid transmission mediated β -lactamase, rendering them resistant to β -lactam antibiotics. The use of a β -lactamase inhibitor such as clavulanate or tazobactam has not resulted in reliable activity against these organisms. They are often also multiply resistant to quinolones and aminoglycosides. Carbapenems have had reliable activity against ESBL organisms despite persistent use.

Lab data – Case 31

Question:

A 79 year old lady is in your ICU being treated for severe necrotising pancreatitis. A blood culture that was taken following a new fever is returned. What therapeutic strategy would you choose?

Blood culture

Site: Blood

Culture: 10^3 cfu Enterococcus faecium (Van-A) isolated

Site: CVC

Culture: 10^4 cfu Enterococcus faecium (Van-A) isolated

Answer:

Strategy:

- Replace all vascular catheters, ideally with a 72 hour gap if feasible, and consider using an antibiotic impregnated catheter
- Send repeat blood cultures from peripheral sites, the old catheters prior to removal and the new catheters once sited. Also send the old catheter tips for culture.

- Start synergid or tygecycline, given the presence of a septicaemia.
- Move the patient to an isolation room and employ full barrier nursing procedures, especially hand washing.

Rationale:

Diagnosis: Vancomycin resistant enterococcus faecium catheter related blood stream infection.

Definitions for a catheter related blood stream infection (CRBSI) vary and include growth of >15 colonies (semiquantitative analysis), or 10^3 + cfu (quantitative analysis), from a distal or proximal catheter segment, or isolation of 5 - 10 times the colony count from a catheter aspirated blood sample as from a peripheral sample, or positive growth from the catheter sample occurs 2 hrs before peripheral sample, in the presence of features of infection. Defervescence of the fevers after removal of a suspect vascular catheter is also accepted as evidence of a CRBSI.

There are 3 levels of vancomycin resistance amongst enterococcal species

- Van-A: High level resistance. Cannot use Vancomycin or Teicoplanin. Use tygecycline (E. faecium & faecalis) or synergid (E. faecium only)
- Van-B: Vanc resistance induceable, but can use Teicoplanin, though long term use may result in resistance
- Van-C 1 - 3: Low level resistance

-

• Lab data – Case 32

• Question:

- A 74 year old gentleman is admitted to the ICU for management of septic shock due to a community acquired pneumonia. He is difficult to ventilate and a CXR shows a large left sided pleural effusion. This is therapeutically tapped and the cloudy fluid sent for analysis. What is your interpretation of the results?

<u>Pleural fluid</u>	<u>Blood</u>
Glucose 0.1 mmol/L	Urea 12.6 mmol/L
Protein 54 g/L	Creatinine 173 μ mol/L
LDH 4522 U/L	Na 135 mmol/L
pH 7.12	K 5.0 mmol/L
	Cl 102 mmol/L
WBC > 10×10^9 /ml	HCO3 24 mmol/L
RBC > 10×10^9 /ml	

Gram stain: Polymorphs + +

Bili 10 μ mol/L

ALT 23 U/L

AST 26 U/L

ALP 34 U/L

GGT 45 U/L

LDH 202 U/L

Protein 64 g/L

Albumin 20 g/L

Glucose 9.2 mmol/L

-
-

- **Answer:**

- Diagnosis: Empyema

- **Rationale:**

- The patient is being treated for a pneumonia, which acts as the source for the empyema. The tapped fluid is cloudy and, by Light's criteria (Effusion to serum protein ratio > 0.5 , effusion to serum LDH > 0.6 , effusion LDH $> 2/3$ upper limit of normal serum LDH), suggests an exudative effusion. Other indicators of an exudate include effusion protein > 30 g/L and a serum to effusion albumin gradient < 1.2 g/L. The low effusion pH and extremely low effusion glucose are very suggestive of an empyema as a cause of the effusion.

Lab data – Case 33

Question:

A 59 year old patient has been in ICU for 6 days, subsequent to an out of hospital cardiac arrest. He has shown a slow neurological recovery and is due to have a tracheostomy placed to facilitate weaning from his ventilator. He began to have febrile episodes on day 4 of his admission and his CXR shows a new right middle lobe infiltrate. A non-directed bronchoalveolar lavage was sent for analysis and the results have returned. What strategies would you employ to minimise the risk of this complication?

Sputum

Appearance: Mucopurulent

RBCs $>10 \times 10^9/\text{ml}$

WBC $> 100 \times 10^9/\text{ml}$

Epithelial $< 10 \times 10^9/\text{ml}$

Organisms seen. GPC in clusters.

Culture: Staph aureus (Mec-A gene detected)

Answer:

Strategies:

1. For prevention of VAP

- Avoid unnecessary intubation
- Minimise duration of invasive ventilation
- Head up 30 - 45 degrees
- Feed enterally rather than parenterally. Benefit possibly offset by presence of NG tube, compromising lower oesophageal sphincter function
- Maintain normoglycaemia, especially DM
- The role of supraglottic suction catheter is not universally accepted as yet
- The roles of selective digestive decontamination or selective oral decontamination remain controversial

2. For prevention of transmission of an MRO

- Adherence to barrier nursing principles
- Hand washing before and after patient contact
- The use of alcohol based hand rubs
- Adherence to the principles of appropriate use of antibiotics in order to minimise the evolution of colonisation to infection
- Minimising the use of invasive devices
- Eliminating infection reservoirs

Rationale:

Diagnosis: Late onset MRSA ventilator-associated pneumonia (VAP)

- A ventilator-associated pneumonia is defined as pneumonia occurring more than 48 hours of initiating mechanical ventilation or within 48 hours of extubation (American Thoracic Society Guidelines definition). It is further classified as early (day 1 – 4 post intubation, community acquired organisms) or late (day 5 or more post intubation, nosocomial organisms), which alters the spectrum of organisms likely to be involved.
- The Mec-A gene confers methicillin resistance on to staphylococcus aureus (MRSA).

• Lab data – Case 34

• Question:

•

- A 63 year old patient who has been ventilated for 8 days for ARDS of unknown aetiology has had a resurgence of febrile episodes. His sputum samples persistently return a growth of a gram negative rod despite therapeutic gentamicin levels and adequate doses of Piperacillin-Tazobactam. What implications does this have for the ICU?

• Answer:

- The concern is the emergence of a multidrug resistant (MDR) Gram negative organism (e.g. Pseudomonas, ESBL, ESCAPM agent, Stenotrophomonas maltophilia). Some acquire resistance, others, like stenotrophomonas, are inherently multiply-resistant environmental gram negative organisms. Its isolation suggests that this patient has been on prolonged broad spectrum antibiotics. The patient must be isolated and strict barrier nursing and contact precautions must be taken in order to prevent horizontal transmission to other patients. Transmission to immunosuppressed, critically ill patients is devastating, especially inherently multiply resistant organisms, such as stenotrophomonas which only have a limited range of effective antibiotics available for their treatment.
- The second concern is that the organism cannot be reached by the antibiotics if, for example, an abscess or a loculated empyema has formed. This requires a focussed assessment in order to determine the most appropriate treatment

Lab data – Case 35

Question:

A 45 year old renal transplant patient is admitted to hospital with fevers, a dry cough and a single episode of haemoptysis. An ICU consult is sought when, on the ward, his oxygen saturation deteriorates and his work of breathing increase, despite increasing his FiO₂ to 15L/min via non-rebreather mask. On examination, he is in moderate respiratory distress and hypoxic with a tachycardia and normal blood pressure. His CXR shows bilateral patchy infiltrates. He is intubated and a bronchoscopic BAL is performed. List the possible responsible organisms and the antimicrobial agent you would commence.

Answer:

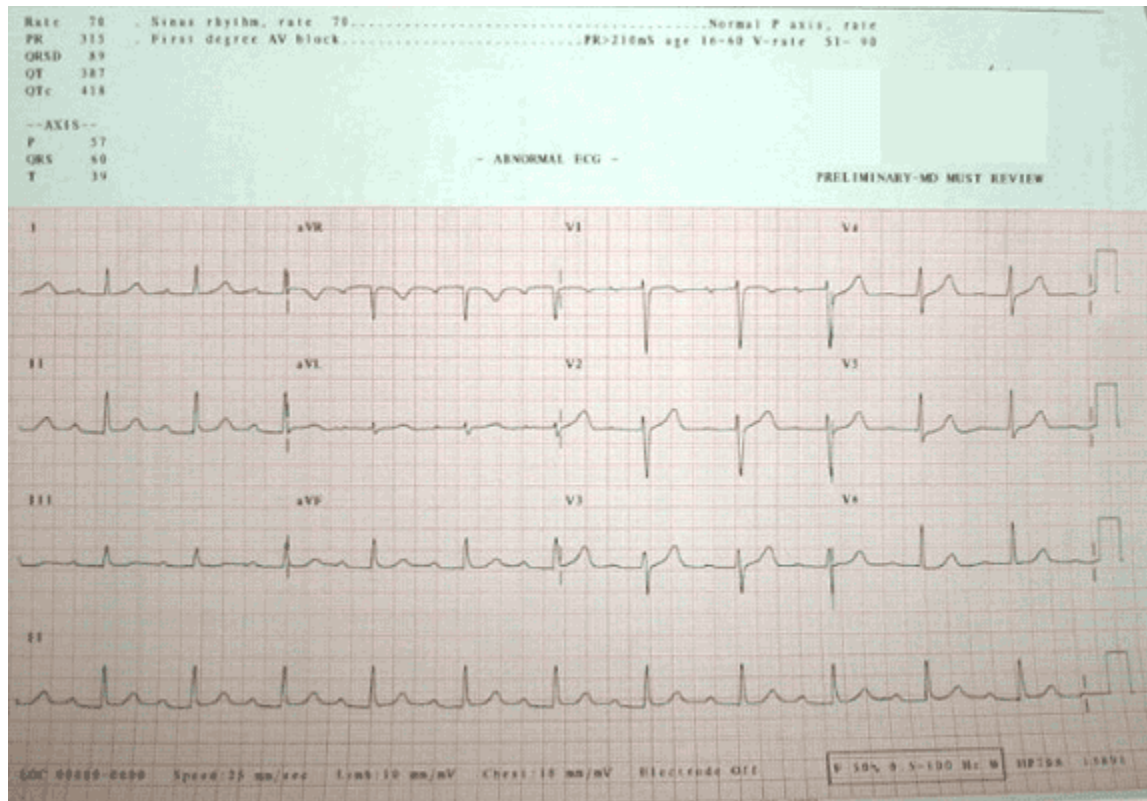
Bacterial	Antimicrobial agent
• Typical	• Benzylpenicillin, ampicillin or ceftriaxone + macrolide (e.g. azithromycin)

<p>community acquired organisms (strep, haemophilus, moraxella)</p> <ul style="list-style-type: none"> • Atypical non-zoonotic community acquired organisms (legionella, mycoplasma, chlamydia pneumonia) • Atypical zoonotic community acquired organisms (chlamydia psittaci, Q fever, Francisella tularensis) • High risk community acquired pneumonia (staphylococcus, enteric gram negative organisms) • Nosocomial organisms • TB <p>Viral</p> <ul style="list-style-type: none"> • CMV • HSV • Chicken pox <p>Fungal</p> <ul style="list-style-type: none"> • Pneumocystis jirovecii (formerly PCP) • Invasive aspergillosis • Invasive candidiasis 	<ul style="list-style-type: none"> • Ampicillin + macrolide (e.g. azithromycin) • Doxycycline, moxifloxacin or a macrolide (e.g. azithromycin) • Flucloxacillin • Ceftriaxone or moxifloxacin • Timentin + gentamicin ± vancomycin • Rifampicin + isoniazid (pyridoxine) + pyrazinimide + ethambutol • Ganciclovir • Aciclovir or Valaciclovir • Aciclovir or Valaciclovir • Co-trimoxazole (Bactrim) • Voriconazole • Generally fluconazole sensitive, unless <i>C. glabrata</i> or <i>C. krusei</i>, in which cases use amphotericin B or voriconazole
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ECG – Case 1

Question:

List 4 conditions associated with this abnormality



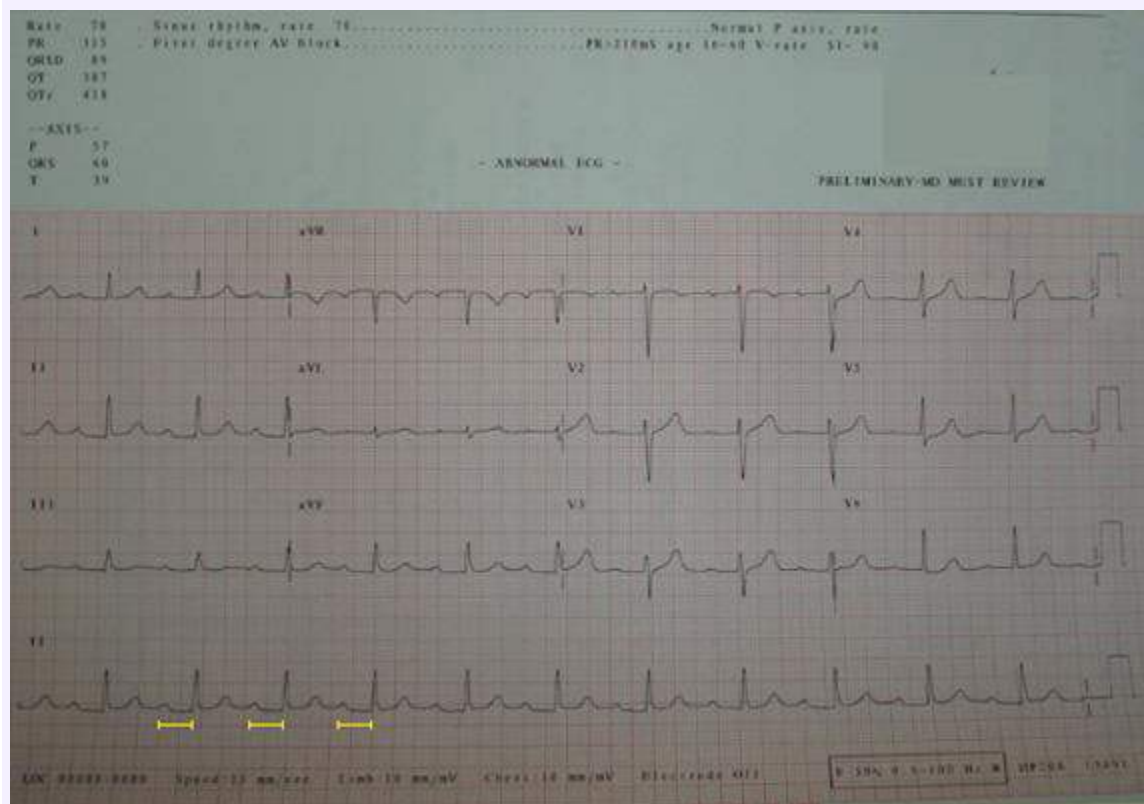
Answer:

Diagnosis = 1st degree heart block

Associated conditions

5. Normal variant
6. Inferior AMI
7. Myocarditis
8. Digoxin toxicity

Also, any cause of increased vagal tone



Rate = 76bpm.

Normal axis.

Sinus rhythm with prolonged PR segment (8 small boxes, or 0.32s – yellow bars)

Normal QRS and QT duration

Normal P, QRS and T wave morphology

examination INTENSIVE CARE

Equipment Cardiovascular Respiratory Renal Gastroenterology Neurology Infection control Other Practical & procedural skills Central venous line insertion Arterial line insertion Pulmonary artery catheter insertion Intra-aortic balloon pump insertion Defibrillation/Electrical Cardioversion Transcutaneous pacing Temporary transvenous pacing wire insertion Pericardiocentesis Intra-osseous needle insertion Standard intubation via the oral route Laryngeal mask insertion Cricothyroidotomy Percutaneous tracheostomy Emergency thoracocentesis Chest drain insertion Small bore catheter insertion Diagnostic bronchoscopy Nasogastric tube insertion Minnesota tube insertion Lumbar puncture Data interpretation Microbiology Transcranial doppler studies Electroencephalography Intracranial pressure

monitoringCardiotocographyCritical care literatureAirway managementAnaesthesiaCardiovascular medicineEthicsFluids and electrolytesGastroenterologyHaematology/transfusionMonitoring devicesNeurologyObstetrics and GynaecologyPain medicinePerioperative medicineQualityRenal medicineRespiratory medicineResuscitation and cardiac arrestSedationSepsisSteroidsToxicologyTraumaPaediatric Critical Care Literature**Recall cases**

Lab data casesLab data – Case 1Lab data – Case 2Lab data – Case 3Lab data – Case 4Lab data – Case 5Lab data – Case 6Lab data – Case 7Lab data – Case 8Lab data – Case 9Lab data – Case 10Lab data – Case 11Lab data – Case 12Lab data – Case 13Lab data – Case 14Lab data – Case 15Lab data – Case 16Lab data – Case 17Lab data – Case 18Lab data – Case 19Lab data – Case 20Lab data – Case 21Lab data – Case 22Lab data – Case 23Lab data – Case 24Lab data – Case 25Lab data – Case 26Lab data – Case 27Lab data – Case 28Lab data – Case 29Lab data – Case 30Lab data – Case 31Lab data – Case 32Lab data – Case 33Lab data – Case 34Lab data – Case 35ECG data casesECG – Case 1ECG – Case 2ECG – Case 3ECG – Case 4ECG – Case 5ECG – Case 6ECG – Case 7ECG – Case 8ECG – Case 9ECG – Case 10ECG – Case 11ECG – Case 12ECG – Case 13ECG – Case 14ECG – Case 15ECG – Case 16ECG – Case 17ECG – Case 18Imaging data casesImaging data – Case 1Imaging data – Case 2Imaging data – Case 3Imaging data – Case 4Imaging data – Case 5Imaging data – Case 6Imaging data – Case 7Imaging data – Case 8Imaging data – Case 9Imaging data – Case 10Imaging data – Case 11Imaging data – Case 12Imaging data – Case 13Imaging data – Case 14Imaging data – Case 15Imaging data – Case 16Imaging data – Case 17Imaging data – Case 18Imaging data – Case 19Imaging data – Case 20Imaging data – Case 21Imaging data – Case 22Imaging data – Case 23Imaging data – Case 24Imaging data – Case 25Imaging data – Case 26Imaging data – Case 27Imaging data – Case 28Imaging data – Case 29Imaging data – Case 30Imaging data – Case 31Imaging data – Case 32Imaging data – Case 33Imaging data – Case 34Imaging data – Case 35Imaging data – Case 36Imaging data – Case 37Imaging data – Case 38Monitoring data casesMonitoring data – Case 1Monitoring data – Case 2Monitoring data – Case 3Monitoring data – Case 4Monitoring data – Case 5Monitoring data – Case 6Monitoring data – Case 7Monitoring data – Case 8Monitoring data – Case 9Monitoring data – Case 10Monitoring data – Case 11Monitoring data – Case 12Monitoring data – Case 13Monitoring data – Case 14Monitoring data – Case 15Monitoring data – Case 16Monitoring data – Case 17Monitoring data – Case 18Monitoring data – Case 19Monitoring data – Case 20Monitoring data – Case 21Clinical casesClinical case 1Clinical case 2Clinical case 3Clinical case 4Clinical case 5Clinical case 6Clinical case 7Clinical case 8Clinical case 9Clinical case 10Clinical case 11Clinical case 12Clinical case 13Clinical case 14Clinical case 15Clinical case 16Clinical case 17Clinical case 18Clinical case 19Clinical case 20Clinical case 21Clinical case 22Clinical case 23Clinical case 24Clinical case 25Clinical case 26Clinical case 27Clinical case 28Clinical case 29Clinical case 30Clinical case 31Clinical case 32Clinical case 33Clinical case 34Paediatric CasePaediatric Case 1Paediatric Case 2Paediatric Case 3Paediatric Case 4Paediatric Case 5Paediatric Case 6Paediatric Case 7Paediatric Case 8Paediatric Case 9Paediatric Case 10Paediatric Case 11Paediatric Case 12Paediatric Case 13Paediatric Case 14Paediatric Case 15Paediatric Case 16Paediatric Case 17Paediatric Case 18Paediatric Case 19Paediatric Case 20Paediatric Case 21Paediatric Case 22Paediatric Case 23Paediatric Case 24Paediatric Case 25Paediatric Case 26Paediatric Case 27Paediatric Case 28Paediatric Case 29Paediatric Case 30Index of casesLab dataECG dataImaging dataMonitoring dataClinical photo casesPaediatric casesTrial Exam

Blank templateAbdominal catastropheAbdominal catastrophe with VAC dressingCardiogenic shockHigh frequency oscillatory ventilation (HFOV)Multiorgan failure (MOF)PolytraumaTraumatic brain injury (TBI)ObstetricPost CABG or valve surgery

Quizzes / Recall Cases > ECG data cases - ECG – Case 2

03:44

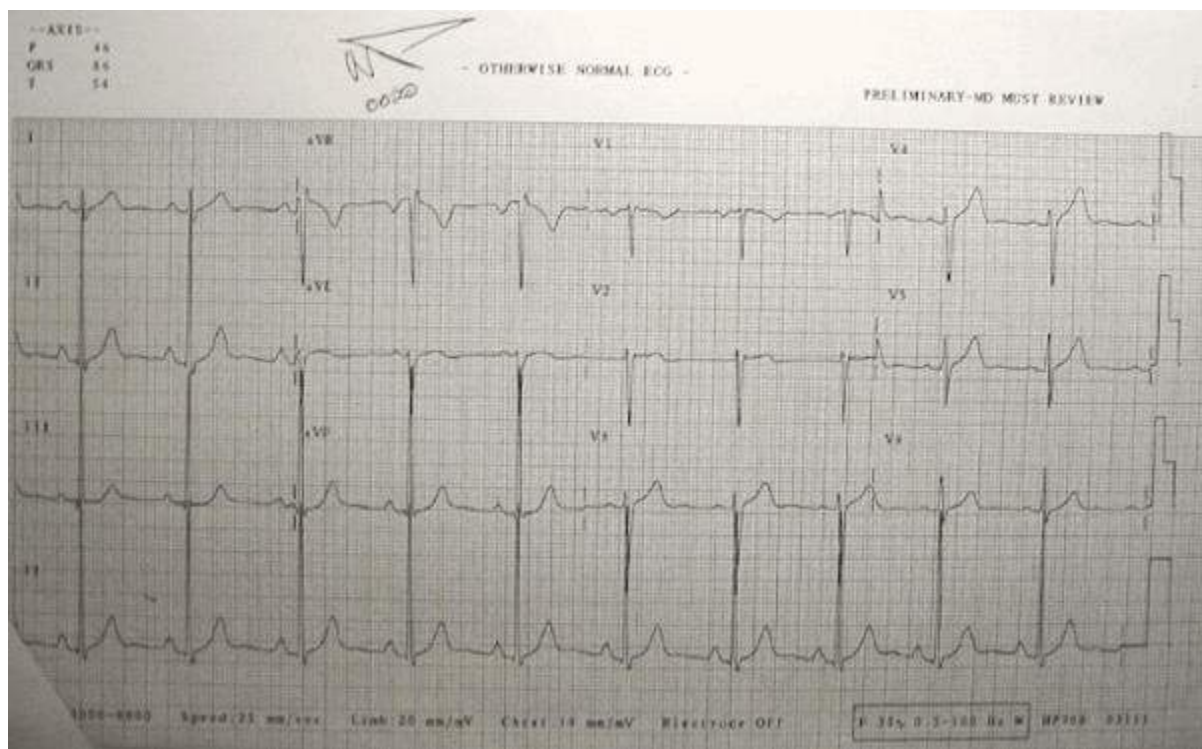
- **ECG – Case 1**
- **ECG – Case 2**
- **ECG – Case 3**
- **ECG – Case 4**
- **ECG – Case 5**
- **ECG – Case 6**
- **ECG – Case 7**
- **ECG – Case 8**

- ECG – Case 9
- ECG – Case 10
- ECG – Case 11
- ECG – Case 12
- ECG – Case 13
- ECG – Case 14
- ECG – Case 15
- ECG – Case 16
- ECG – Case 17
- ECG – Case 18

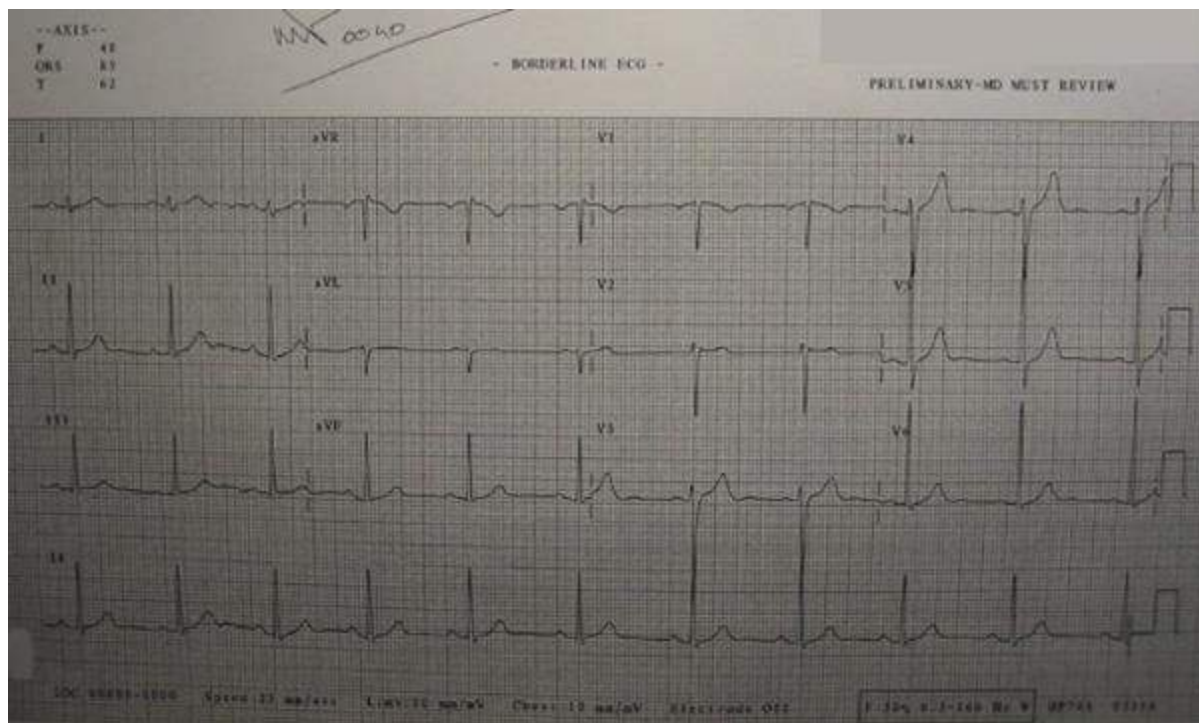
ECG – Case 2

Question:

- a) Describe the features of this ECG



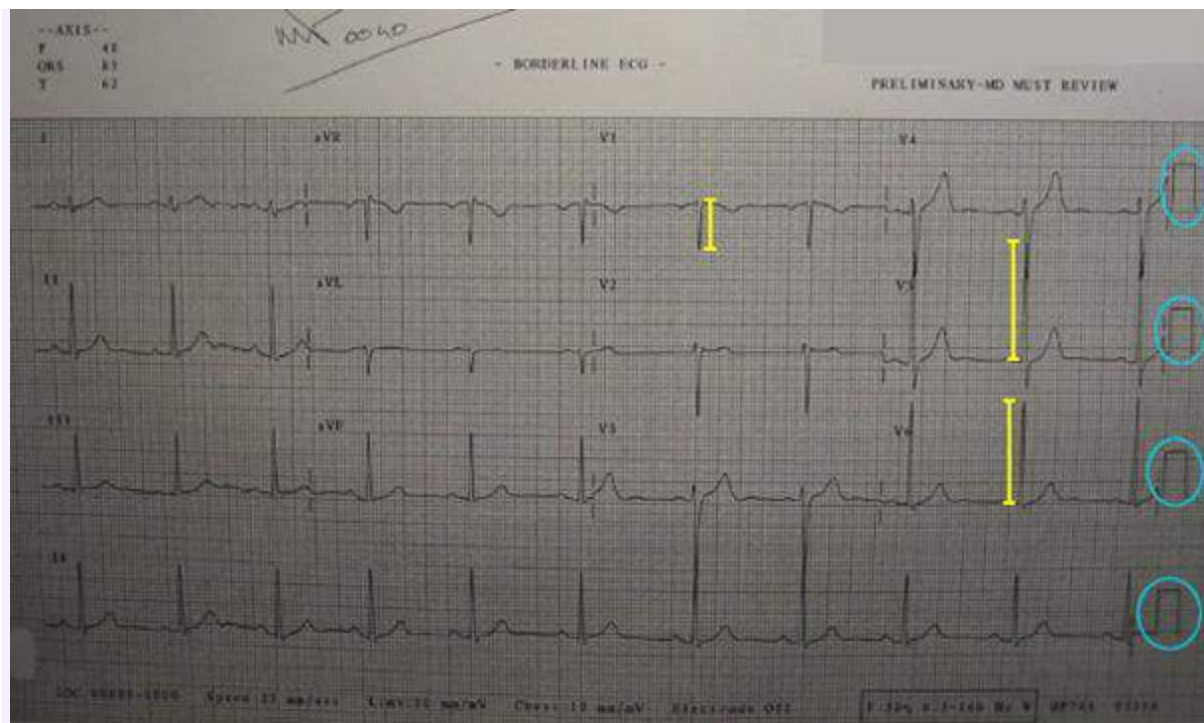
- b) With the voltage calibration corrected, describe the ECG as shown below



Answer:

Description: There is a voltage calibration error (yellow circles), resulting in distortion of the height of the P and T waves and the QRS complexes. The paper speed is correct (25mm/sec), so the rhythm is sinus at about 60bpm.

Diagnosis = Voltage calibration error



Voltage criteria for LVH

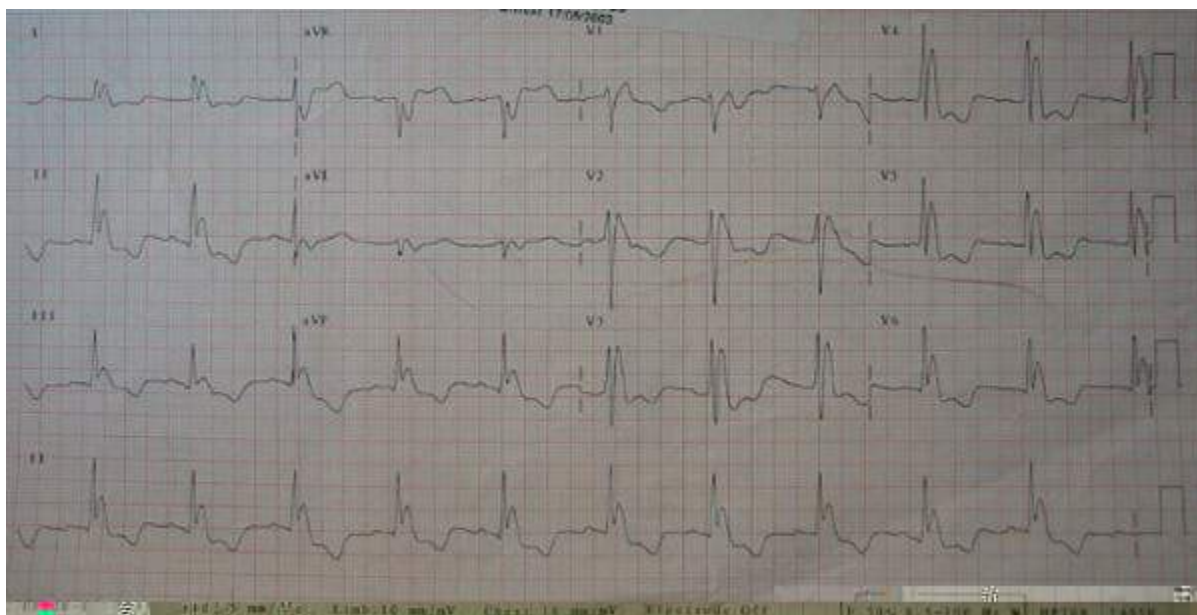
There are a variety of voltage criteria used to identify LVH, with specificities that are generally good (86 - 100%) but with poor sensitivities (1.5 - 55%). They include:

- S wave in V1 + R wave in V5 or V6 > 35 mm if age > 40yo, > 40 mm if age 30 to 40yo, > 60 mm if age 16 to 30yo (Sokolow-Lyon indices; sensitivity 40%, specificity 95%) (yellow bars).
- R wave in I + S wave in III > 25mm
- R wave in aVL > 11mm
- R wave in aVF > 20mm
- R wave in V5 or V6 > 26mm

ECG – Case 3

Question:

List 3 measures that are used to manage the condition indicated by the following ECG.



Answer:

Diagnosis = Hypothermia

Management:

4. Warm air blanket; e.g. Bair hugger
5. Warmed IV fluids
6. Warmed, humidified oxygen

Depending upon the severity of the hypothermia and the stability of the patient's condition, additional therapeutic modalities include warm fluid gastric lavage, warm fluid bladder irrigation, warm fluid peritoneal lavage, dialysis, endovascular warming catheter and cardiopulmonary bypass.

Rationale

Description

Borderline sinus bradycardia at 60bpm

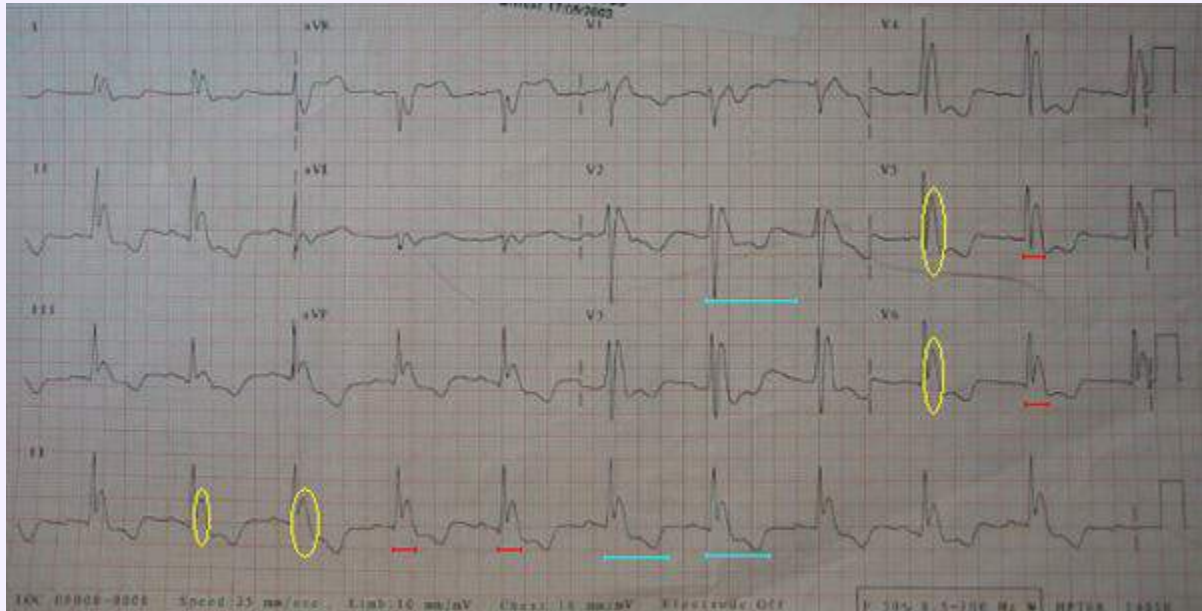
Normal axis

Prominent J-waves (Osborne waves – yellow circles) which indicate severe hypothermia (the height of the J-waves roughly correlates with the severity of the hypothermia).

Widened QRS complex (red bars), predominantly due to the J-waves

Widened QT segment (blue bars)

The PR segment is also often prolonged in hypothermia, but not in this case



ECG – Case 4

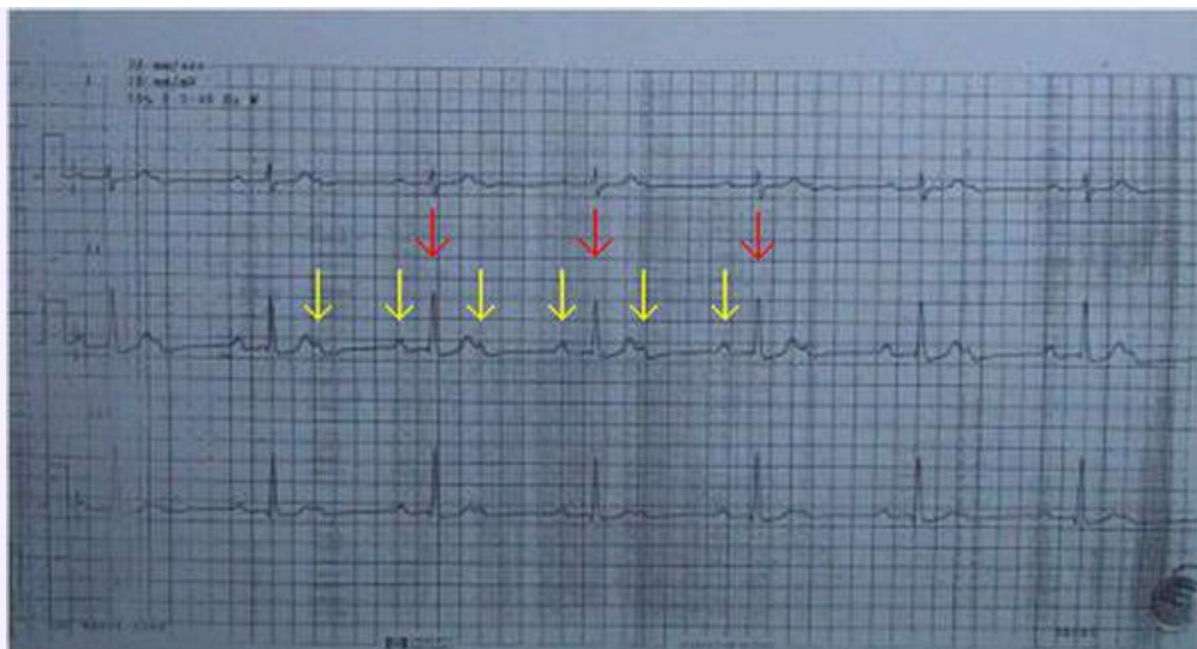
Question:

What associated pathology would you check for given the features of this ECG?

Answer:

Diagnosis = Mobitz type II 2nd degree heart block with 2:1 block

Associated pathology: Evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)



Description:

A normal morphology QRS complex (red arrows) follows every second P wave (yellow arrows) at regular intervals.

The P waves are spaced at regular intervals and are of normal morphology (as they originate from the sinus node)

The ventricular rate is approximately 40bpm

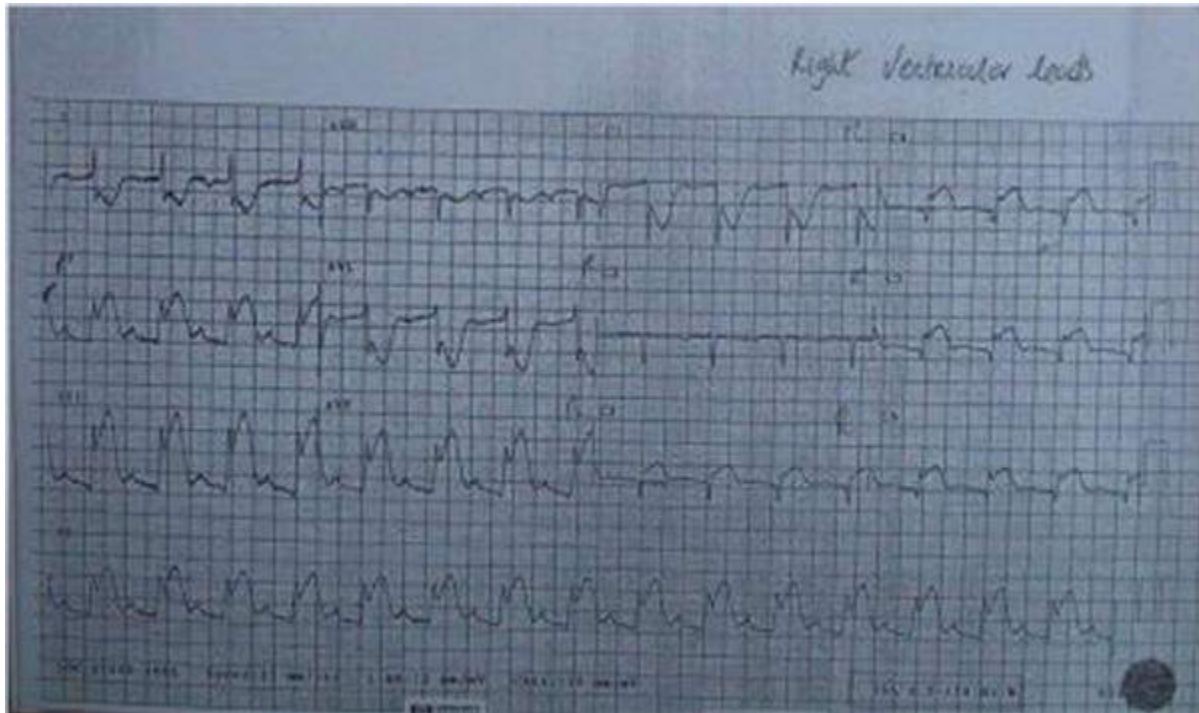
The axis is normal

There is no evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)

ECG – Case 5

Question:

What are the principles of managing this condition?



Answer:

Diagnosis = Right ventricular acute myocardial infarct with posterior extension and first degree heart block

Principles:

5. Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.
6. Hypotension is common and treated with volume resuscitation. Once euvolaemic, dobutamine may benefit. Cannot use CVP to guide volume status as it is elevated due to a failed right ventricle.
7. Analgesia – avoid nitrates, which can precipitate severe hypotension
8. Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)

Description

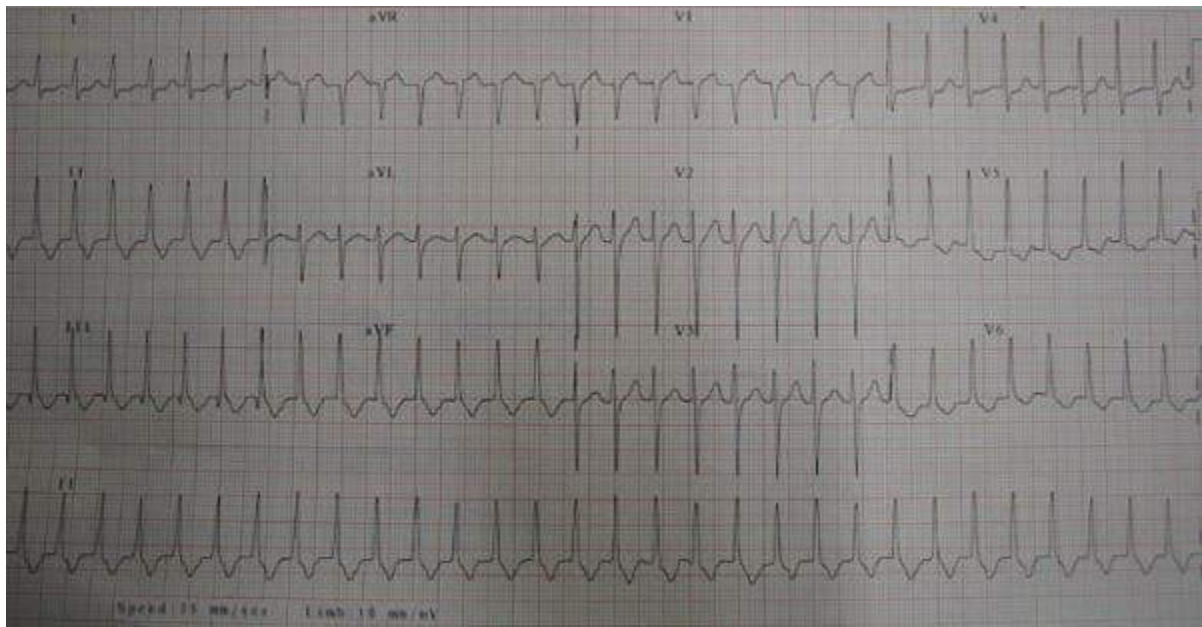
Significant ST elevation with hyperacute T waves in the inferior leads (II, III and aVF; yellow circles). Any inferior ischaemic event should prompt a search for

- A heart block – in this case there is a 1st degree heart block (green bars)
- A right ventricular AMI, especially if the ST elevation in lead II is higher than lead II, by performing a right ventricular ECG (red ellipse) where V 1 – 6, or just V4 alone, are placed in a mirror image position to their usual place on the chest and labelled V1R – V6R. The V4R to V6R leads (blue circles) demonstrate a similar appearance to a lateral AMI, but as they lie over the right ventricle, reflect an RV infarct.
- A posterior AMI (white ellipse) – flip the ECG over and bottom edge up and the waveform will look like a typical ST elevation AMI, or, perform a 15 lead ECG where leads V7 to V9 continue around from V6 to the posterior aspect of the chest.

ECG – Case 6

Question:

List 4 methods of treating this arrhythmia.



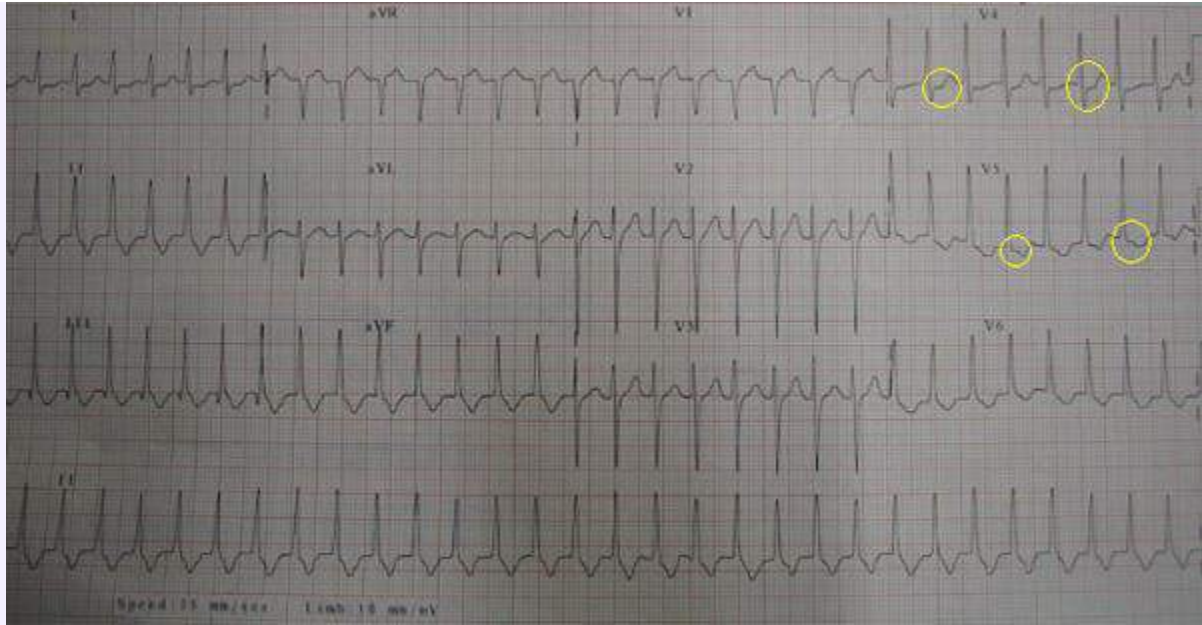
Answer:

Diagnosis = SVT (AVNRT)

Treatment

- Synchronised cardioversion (If hypotensive, evidence of cardiac ischaemia, evidence of heart failure or failed drug therapy. Potentially harmful if the SVT is due to digoxin toxicity.)
- Vagal manoeuvre – e.g. carotid massage, facial cold water immersion, Valsalva manoeuvre
- Adenosine IV in increments of 6mg to a maximum of 18mg, as a rapid bolus
- Verapamil 5mg IV over 1 – 2 minutes, unless accessory pathway (AVRT – see below) suspected

Additional alternatives include IV propranolol 0.5 – 1mg IV over 1 minute repeated every 5 minutes, metoprolol 5mg over 1 – 2 minutes every 5 minutes and external overdrive pacing at the SVT rate + 40bpm for 10 beats at 120mA.



Description

A regular narrow complex tachycardia with a ventricular rate of approximately 180bpm (therefore less likely to be atrial flutter, which usually runs at 150 or 300bpm)

There are no visible P waves, suggesting that this is an AV nodal re-entrant (AVNRT) SVT.

An AV re-entrant (AVRT) SVT is composed of an accessory pathway and the AV node, which requires the electrical impulse to travel between the two; orthodromic if it travels from AV node to accessory pathway and antidromic in the opposite direction. The resultant P wave is therefore usually seen after the QRS complex; i.e. the retrograde P wave, which shows up as a small negative deflection between the QRS complex and the T wave, or as a dent in the upstroke of the T wave. However, it may be difficult to confidently differentiate an AVRT from an AVNRT and it would make you less enthusiastic about using verapamil for chemical cardioversion.

ECG – Case 7

Question:

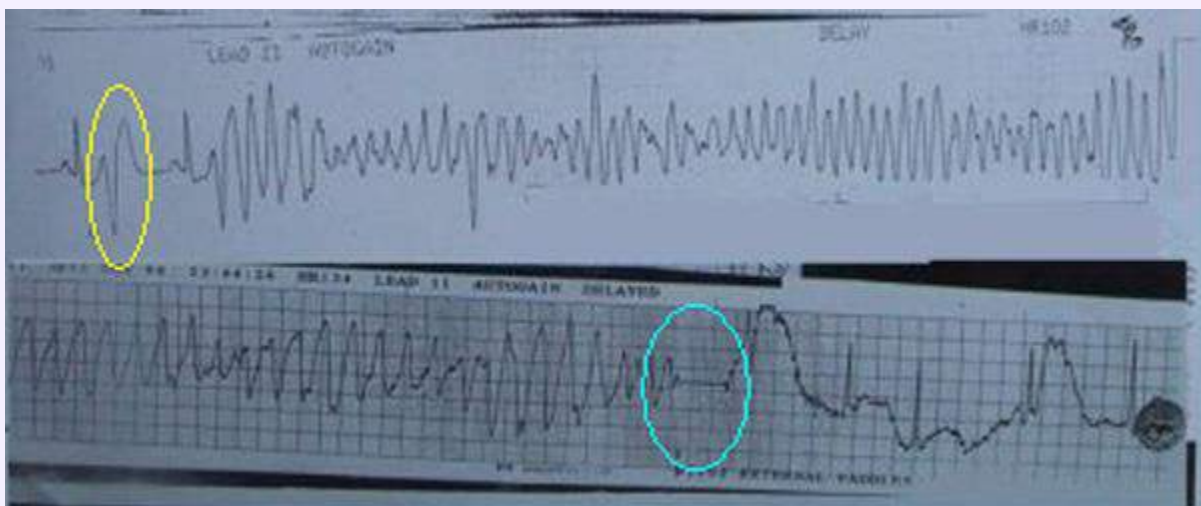
Please interpret the sequence of events in this rhythm strip. What underlying ECG deficit would you look for?



Answer:

Diagnosis = VPC resulting in R-on-T induced Torsades de pointes (polymorphic VT) at the start of the upper rhythm strip and subsequent cardioversion near the middle of the lower rhythm strip. There is no evidence of a large voltage spike prior to the cardioversion, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of $MgSO_4$.

I would look for a prolonged QT segment on the post reversion ECG. It is not evident on this strip.



Description

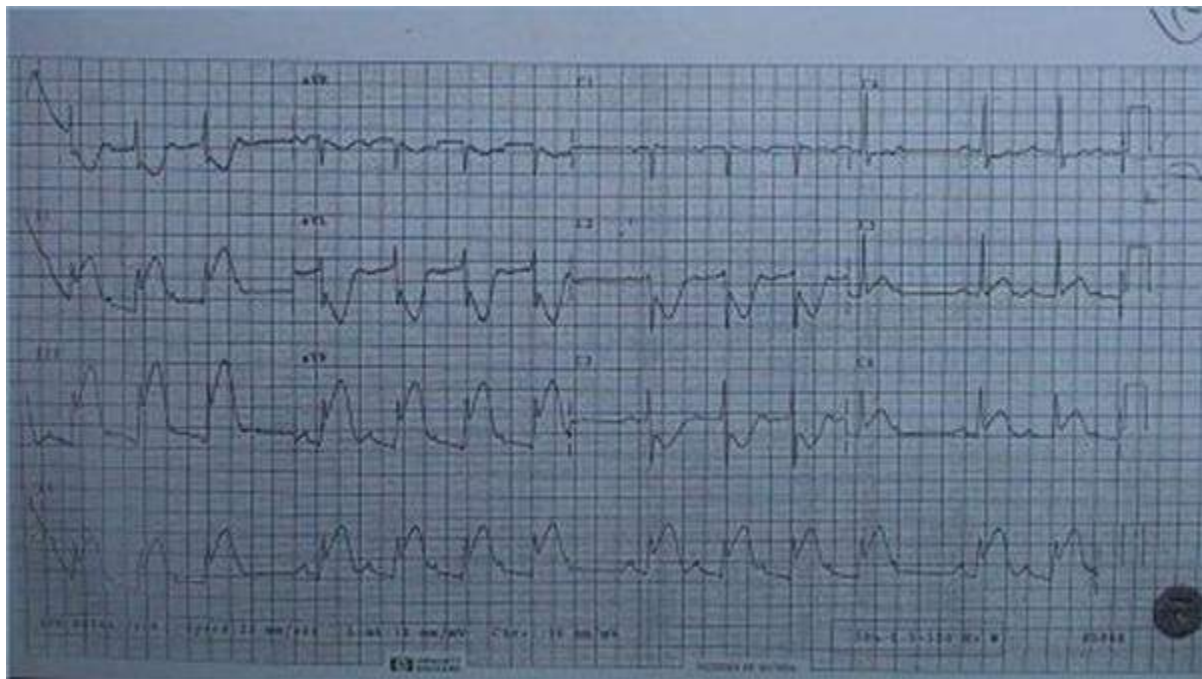
The upper rhythm strip demonstrates a VPC (yellow circle) occurring on top of the T wave of the preceding QRS complex. It probably recurs after the second QRS complex, as polymorphic VT ensues which varies both in the height and width of the complexes.

Midway through the lower rhythm strip, the VT terminates and reverts to a narrow complex rhythm that does not have an obviously prolonged QT segment (See below). At the point that the polymorphic VT terminates (blue circle) there is no evidence of a large voltage spike, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of MgSO₄.

ECG – Case 8

Question:

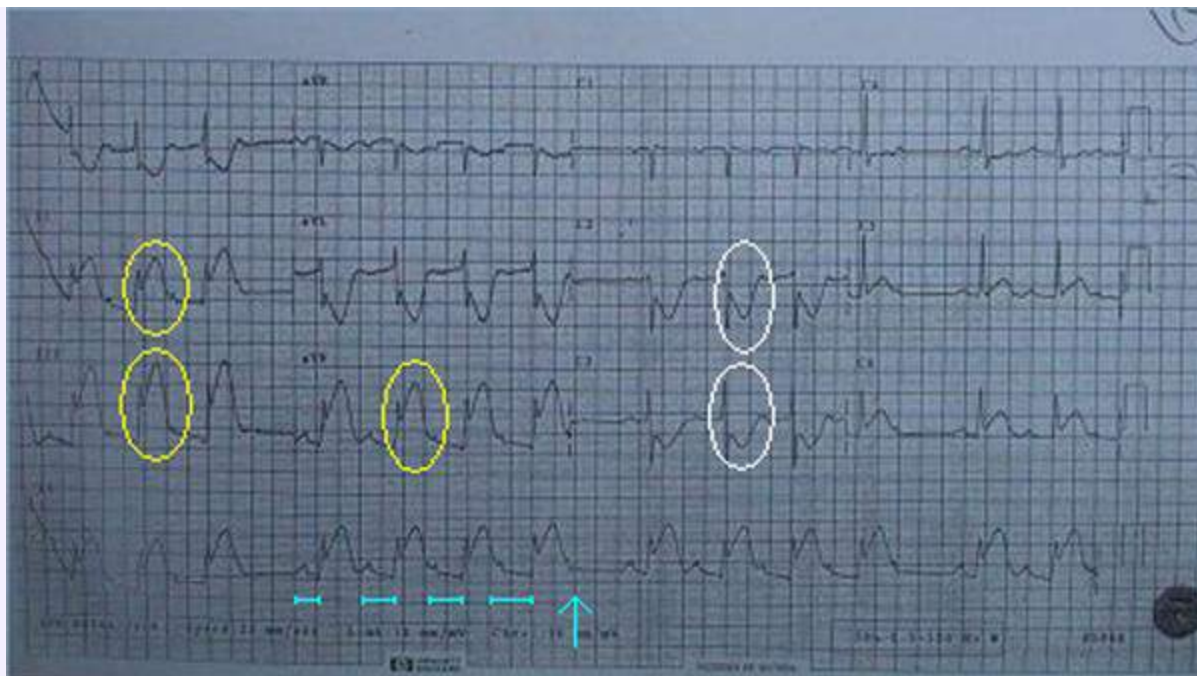
What pathologies are demonstrated on this ECG? What ECGs would you perform next?



Answer:

Pathologies = Inferoposterior acute myocardial infarction with Mobitz type I block (Wenkebach phenomenon)

The next ECGs: A right ventricular lead ECG, to exclude an RV infarct and a 15 lead ECG to confirm the presence of a posterior AMI.



Description

Significant ST elevation with hyperacute T waves in the inferior leads (II, III and aVF; yellow ellipses)

ST depression with inverted T waves, suggestive of a posterior AMI, in leads V2 and V3 (white ellipses)

The rhythm strip demonstrates a PR segment that lengthens progressively (blue bars) until a P wave fails to conduct through to the ventricles (blue arrow). This cycle repeats at a regular interval; in this case, every 5th P wave fails to conduct.

Remember, any inferior ischaemic event should prompt a search for:

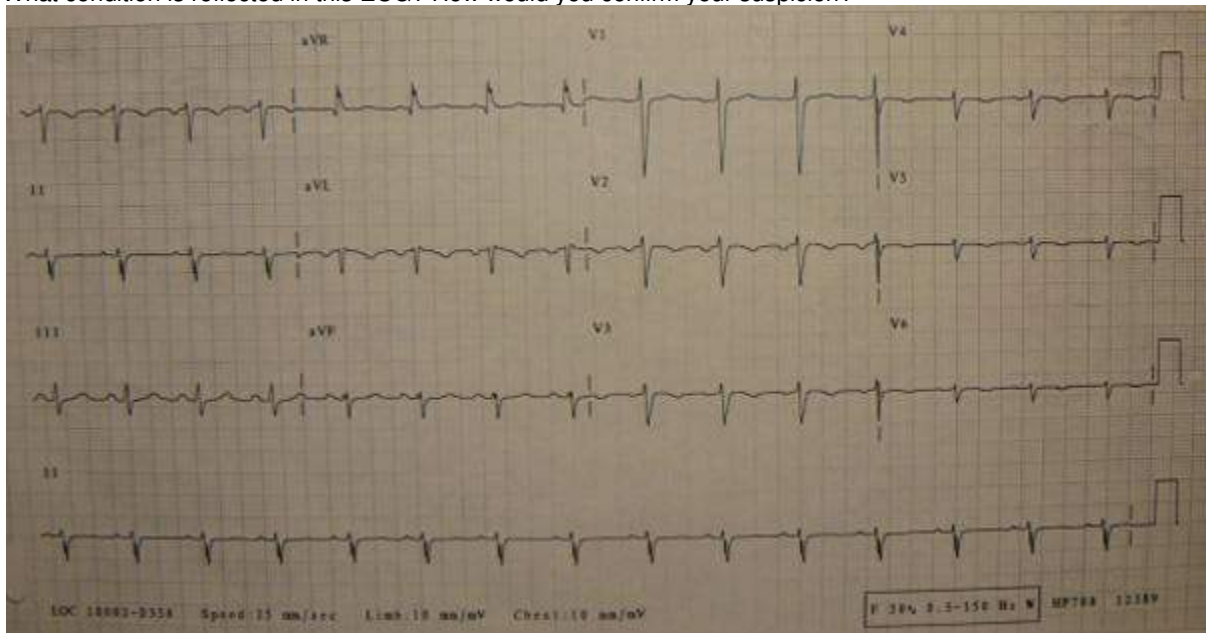
- A heart block – in this case there is a 1st degree heart block
- A right ventricular AMI, especially if the ST elevation in lead II is higher than lead III, by performing a right ventricular ECG where V1 – V6, or just V4 alone, are placed in a mirror image position to their usual place on the chest and labelled V1R – V6R. The V4R to V6R leads demonstrate a similar appearance to a lateral AMI, but as they lie over the right ventricle, reflect an RV infarct.
- A posterior AMI – flip the ECG over and bottom edge up and the waveform will look like a typical ST elevation AMI, or, perform a 15 lead ECG where leads V7 to V9 continue around from V6 to the posterior aspect of the chest.

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- ECG – Case 9

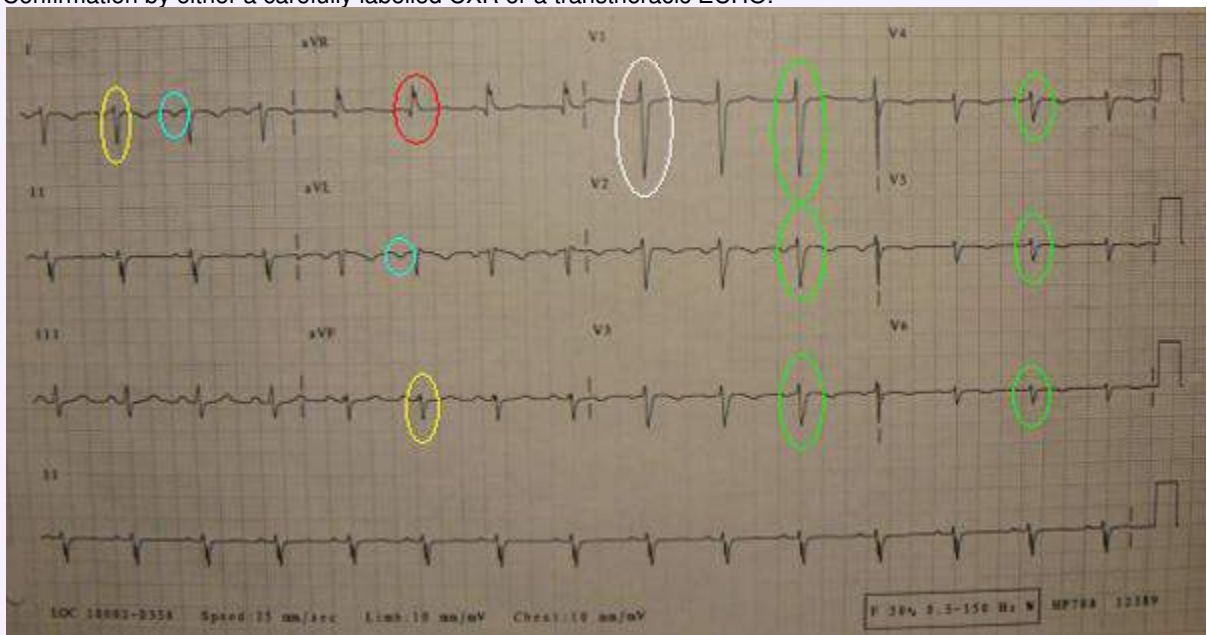
- **Question:**

- What condition is reflected in this ECG? How would you confirm your suspicion?



- **Answer:**

- Diagnosis = Dextrocardia
- Confirmation by either a carefully labelled CXR or a transthoracic ECHO.



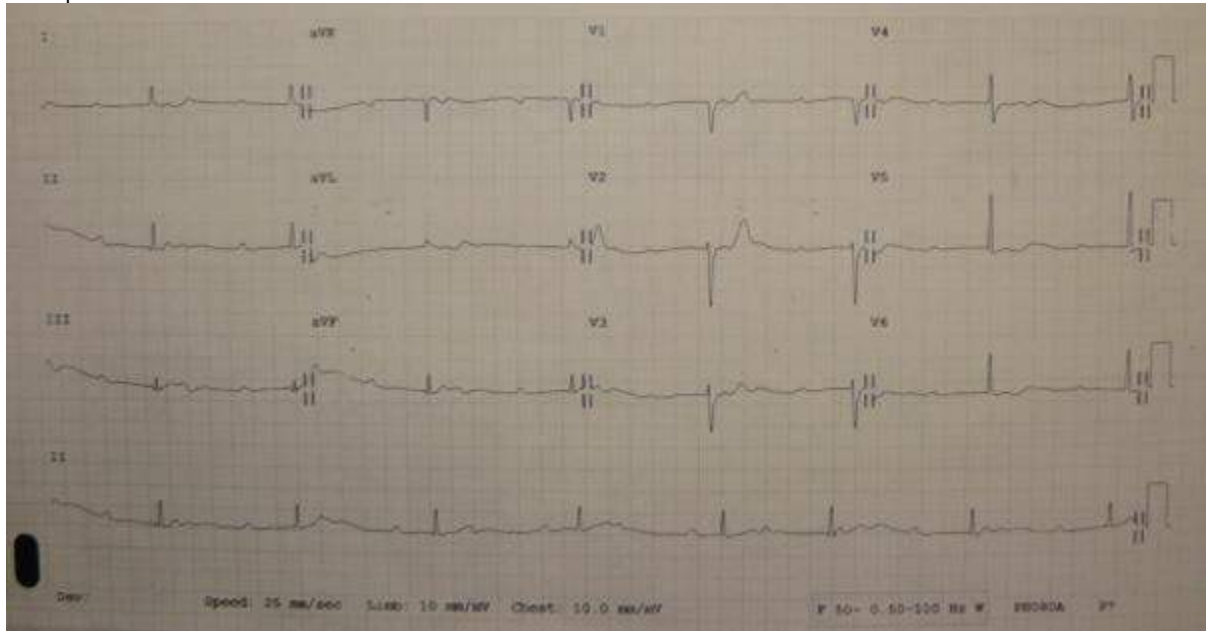
- **Description**

- Extreme right axis (yellow ellipses)
- Negative deflection P waves in leads I and aVL (blue ellipses)
- QRS in aVR (red ellipse) looks like a normal aVL complex
- Presence of an RV1 (white ellipse)
- Poor R wave progression from V1 to V6

- **ECG – Case 10**

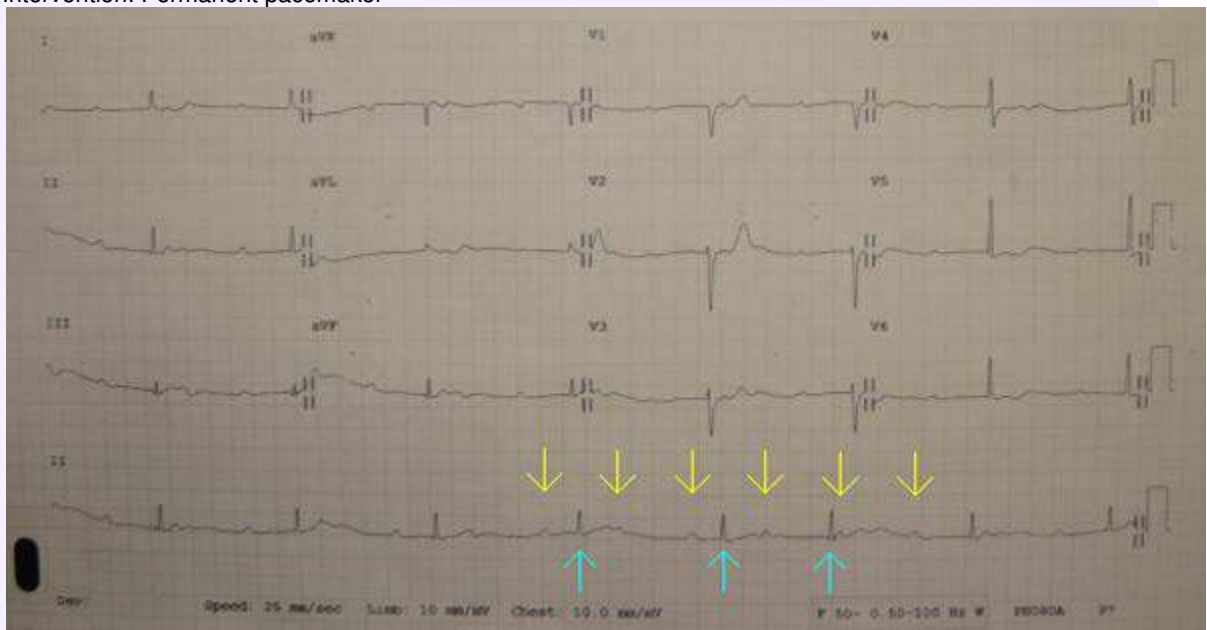
- **Question:**

- What physiological disturbance might you expect as a result of this ECG? What definitive intervention may be required?



- **Answer:**

- Diagnosis = Complete heart block
- Physiological disturbance: Hypotension
- Intervention: Permanent pacemaker



- **Description**

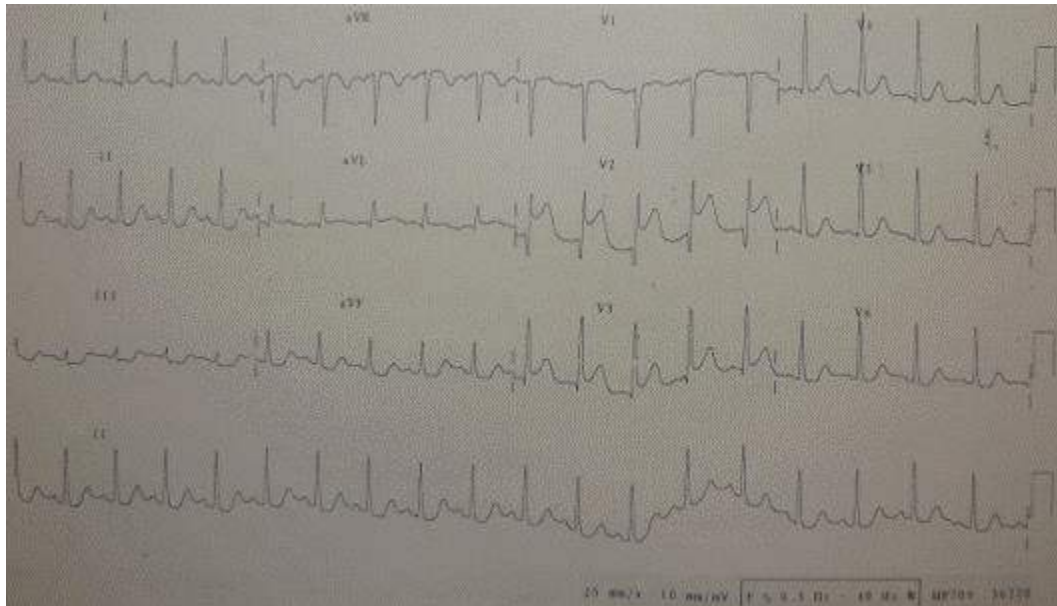
- Normal morphology P waves occurring at a regular interval (yellow arrows) and independent of the occurrence of QRS complexes (blue arrows)
- The ventricular rate is approximately 50bpm and is probably junctional in origin (narrow complex)

- No evidence of an inferior ischaemic event on this ECG (Always look for this when you identify a heart block pattern!)

ECG – Case 11

Question:

Outline your management of a patient who develops the following ECG.



Answer:

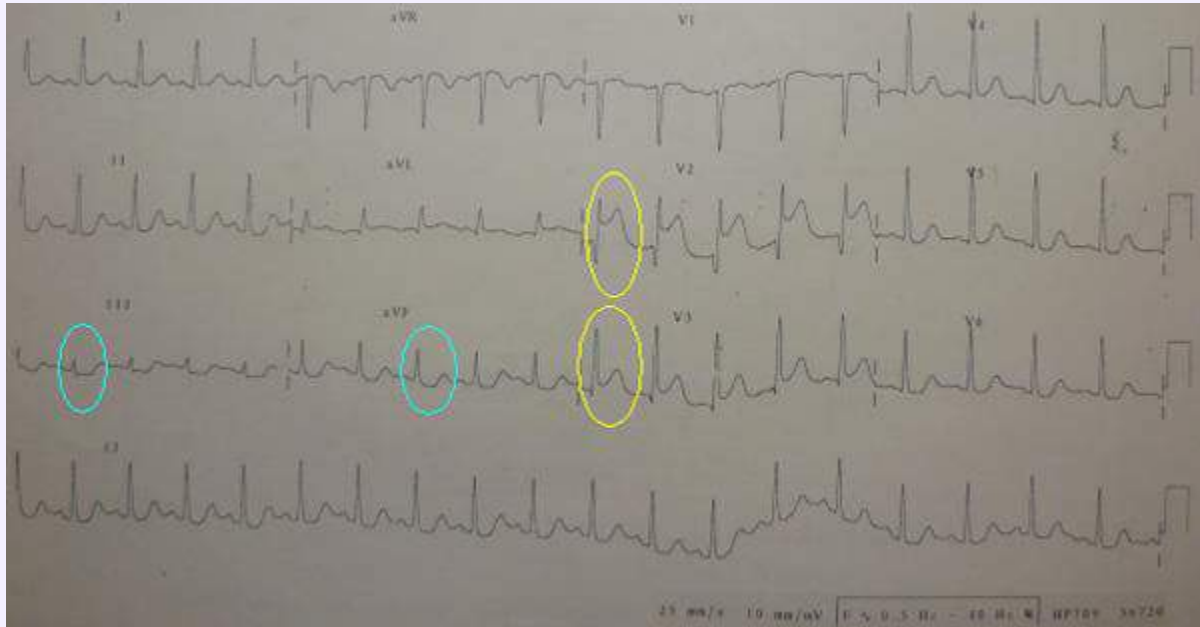
Diagnosis = Anteroseptal AMI with reciprocal changes in the inferior leads

Management:

10. Resuscitation as required

- support oxygenation and ventilation
 - support blood pressure with IV fluid and, if necessary, an inotrope such as adrenalin
- Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.
- Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)
- Analgesia – sublingual nitrate, IV morphine
- IV heparin for a minimum of 48 hours, aiming for an aPTT of 60 - 90s
- β -blockade aiming for a HR of 60 – 90bpm
- Screen for remediable risk factors
- Monitor for complications of an AMI, especially heart failure in this context.
- Start a myocardial remodeller, e.g. ACE inhibitor or carvedilol, once that patient is stable.

Rationale:



Description

Significant ST segment elevation with hyperacute T waves in V2 and V3 (yellow ellipses) and ST depression in leads III and aVF.

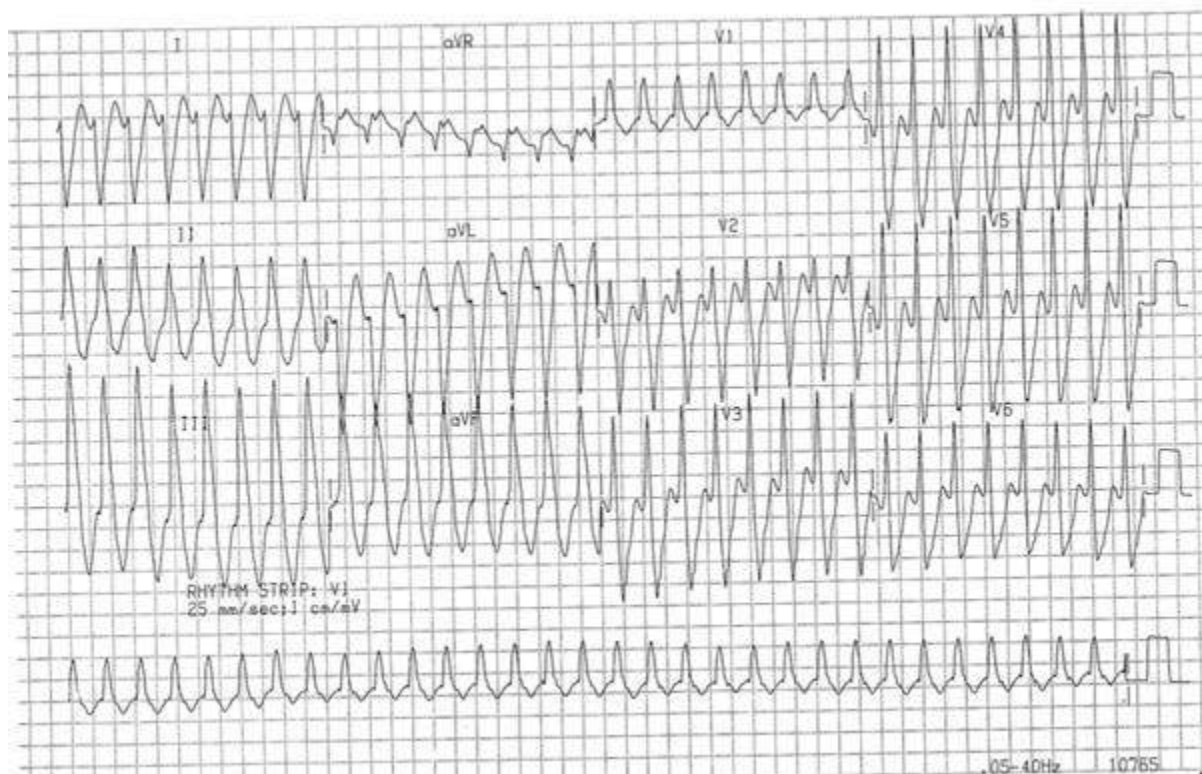
This pattern suggests an LAD lesion, which is likely to be proximal.

The lateral region is unaffected, suggesting that the circumflex has been spared and therefore the left main artery is not involved.

ECG – Case 12

Question:

What ECG features would you use to determine the source of this tachyarrhythmia?



Answer:

Diagnosis = Broad complex tachycardia, likely to be an SVT with aberrant conduction.

Features used to differentiate between a VT and an SVT with aberrant conduction

VT

- Concordance – i.e. all of the QRS complexes point in the same direction, either positive or negative
- Fusion beats – an atrial impulse is conducted successfully through to the ventricle and merges with a VT wave, producing a complex with a bizarre broad morphology
- Capture beats - an atrial impulse is conducted successfully through to the ventricle, resulting in the appearance of a normal P-QRS complex amidst the VT activity
- AV dissociation – P waves may be visible intermittently, but are not conducted effectively
- Leftward axis
- QRS > 140ms (3½ small boxes)

SVT with aberrance

3. Essentially the opposite of VT, although the QRS duration may be similarly prolonged, particularly if there is a pre-existing or rate-related BBB
4. If the broad complex tachyarrhythmia is irregular, then the decision is between VF (no output) and AF with aberrancy (may be hypotensive)

Description

A regular, broad complex tachyarrhythmia at approximately 160bpm

Right axis, possibly due to a rate-related BBB, consistent with an SVT with aberrancy

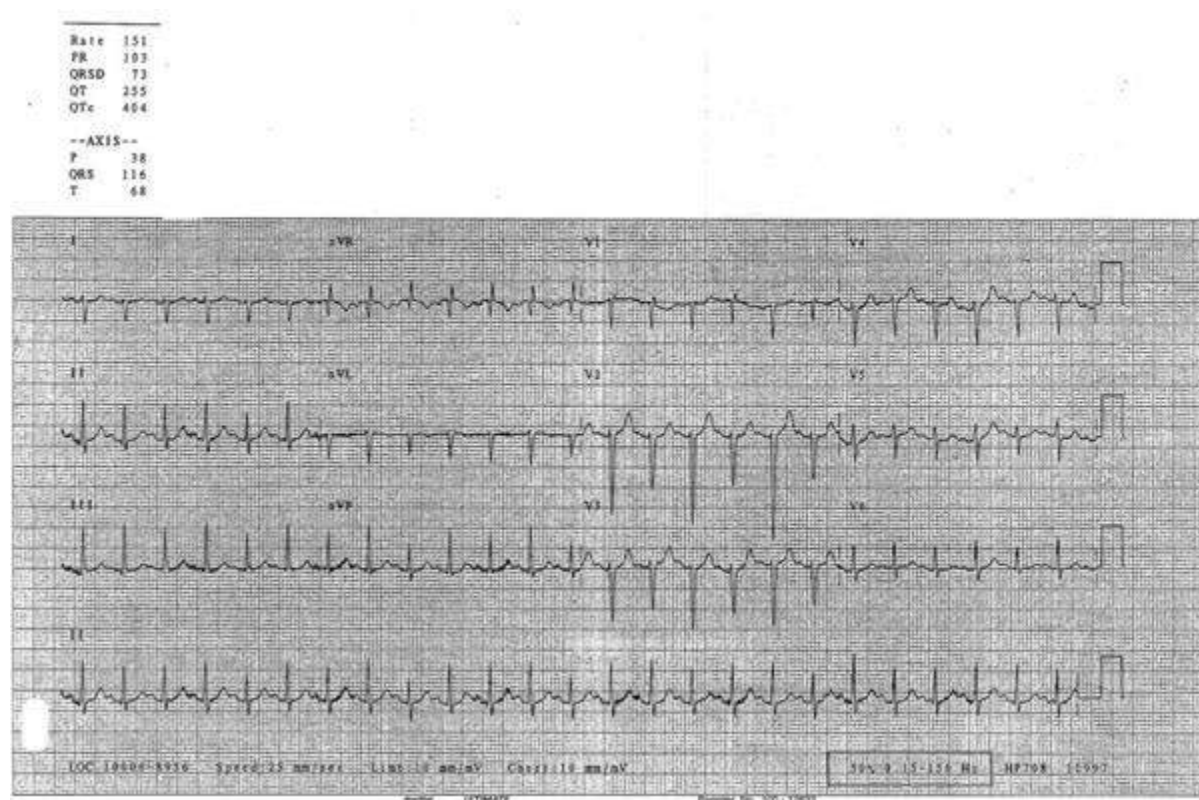
No visible P-waves, fusion beats or capture beats

Absence of a visible P-wave suggests an AVNRT

ECG – Case 13

Question:

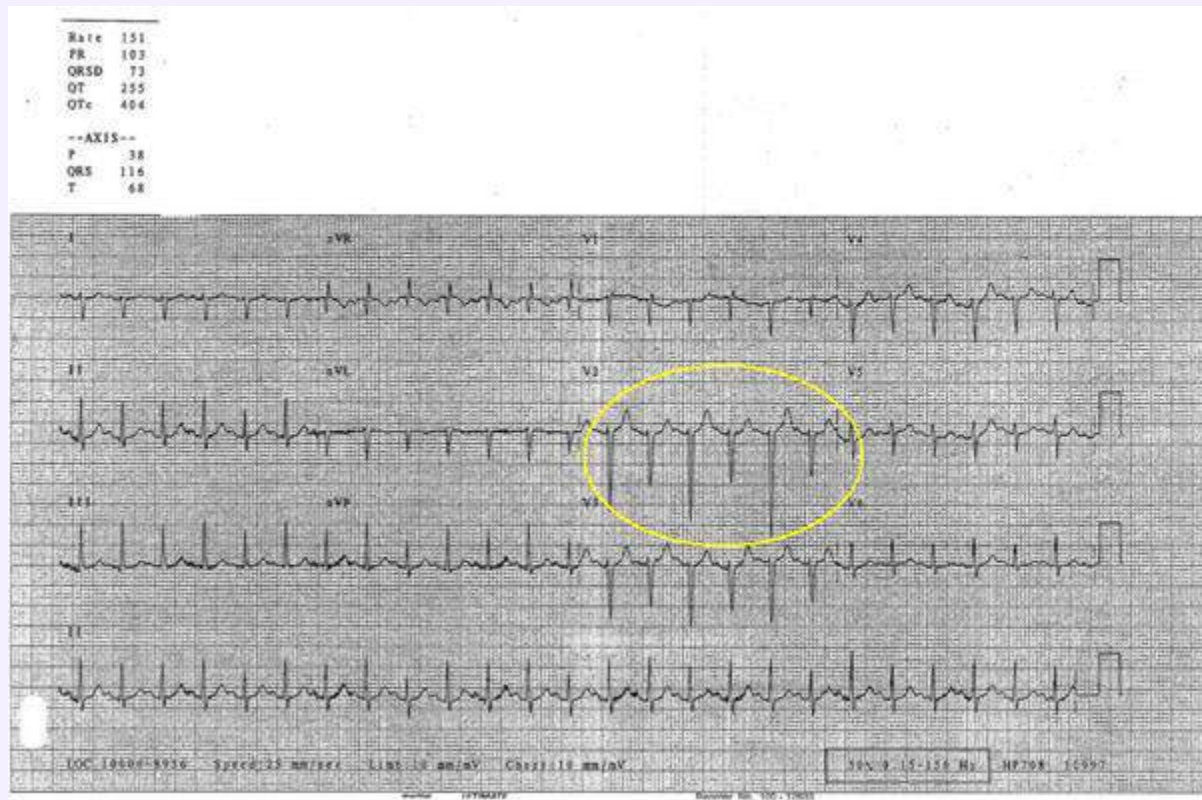
How would you confirm the diagnosis? What therapeutic intervention would you consider for a hypotensive patient with the following ECG?



Answer:

Diagnosis = Electrical alternans, pathognomonic of a pericardial effusion

Therapeutic intervention: Pericardiocentesis. If recurrent, a pericardial window may be required.

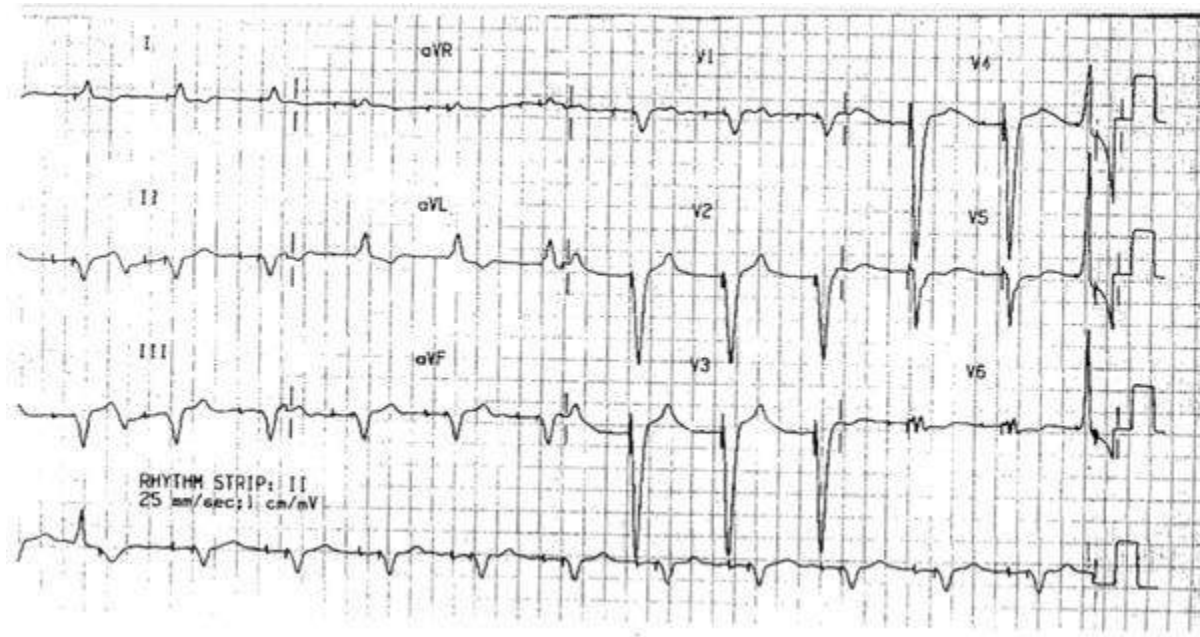


There are no ischaemic features

ECG – Case 14

Question:

List 6 causes of the following ECG abnormality.



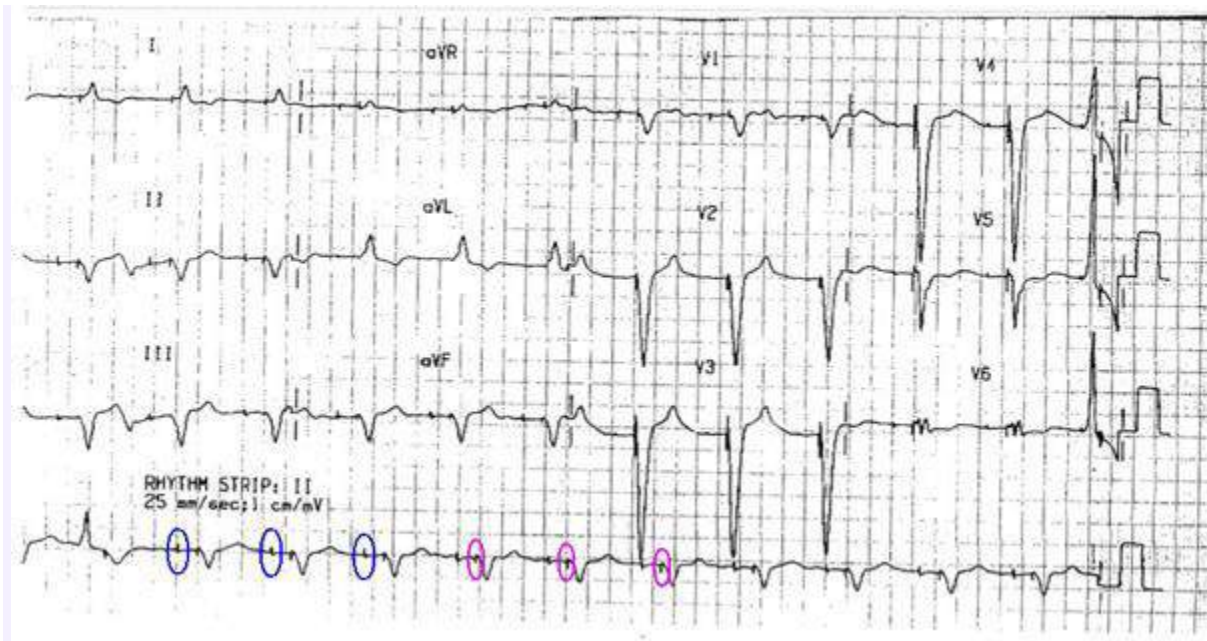
Answer:

Diagnosis = Failure of atrial lead capture in a dual lead pacemaker

Causes:

- Physiological failure – Pacemaker discharge occurs during the myocardial refractory period. (Resolved by reprogramming the pulse generator.)
- lead fracture
- fibrosis at the lead tip
- hyperkalaemia
- hypoxaemia
- myocardial ischaemia

Also consider antiarrhythmic drug toxicity.



Description

Atrial pacing spikes (Blue ellipses) which do not result in a visible atrial impulse.

There are ventricular pacing spikes (Pink ellipses) consistently followed by a broad QRS complex, suggesting that the ventricular pacing wire is functioning properly.

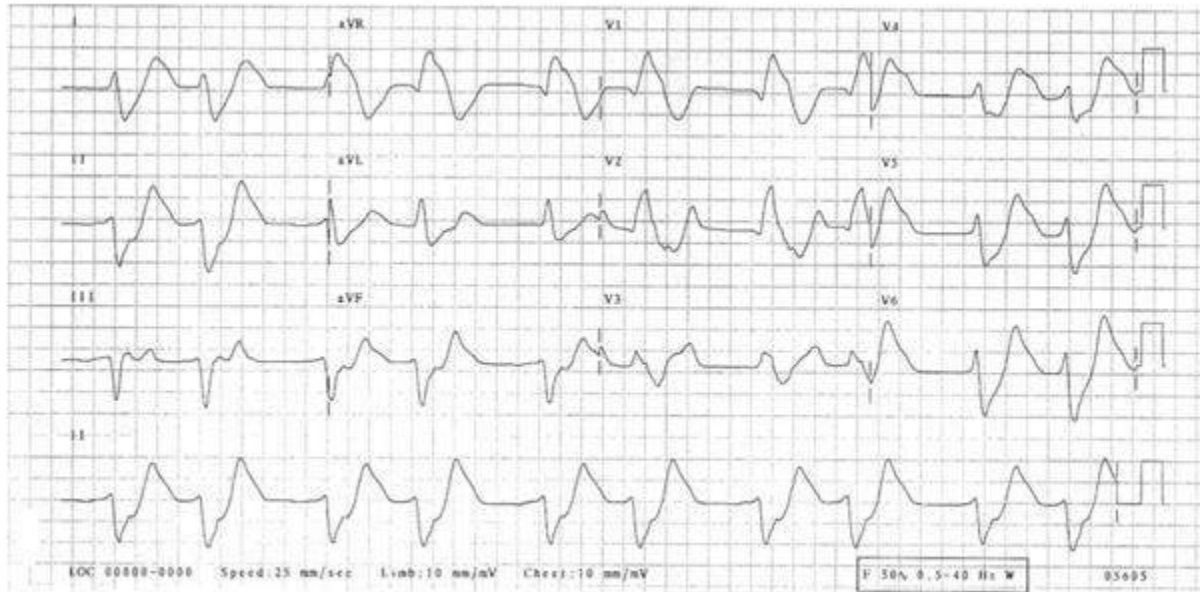
The pacemaker rate is approximately 80bpm.

There is a leftward axis, typical of a right ventricular pacing wire

ECG – Case 15

Question:

List the therapeutic interventions, along with an indication of time to effect and the mode of effect, for a patient with the following ECG



Answer:

Diagnosis = Hyperkalaemia

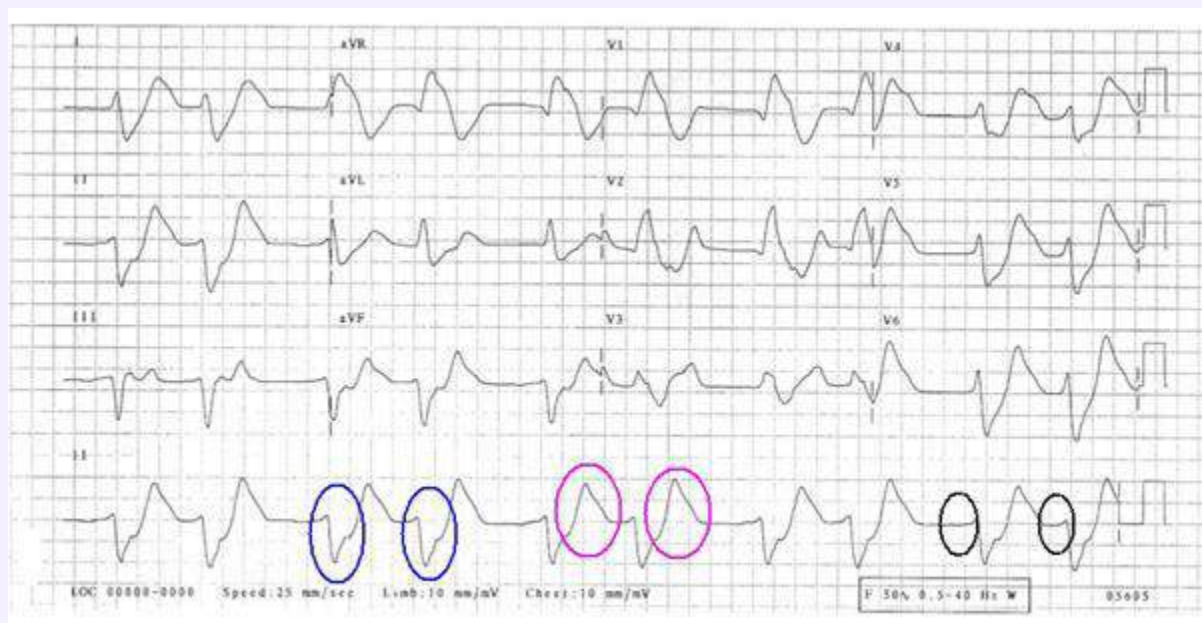
Therapeutic strategies

Therapy	Time to effect	Mode of effect
Calcium chloride 10mls 10%	Seconds to minutes	Stabilises myocardium from effect of hyperkalaemia. Avoid if digoxin toxicity suspected
0.5 – 1mEq/kg NaHCO ₃ 8.4% IV	Several minutes	Intracellular K ⁺ shift
50mls 50% Dextrose + 10U Actrapid	20 – 40 minutes	Intracellular K ⁺ shift

<p>insulin IV</p> <p>(Arguably, if the person is not a diabetic, the dextrose challenge should stimulate sufficient native insulin to achieve the desired effect)</p>		
<p>Continuous nebulised salbutamol</p>	<p>20 – 40 minutes</p>	<p>Intracellular K⁺ shift.</p> <p>(Better efficacy in paediatric population than adults)</p>
<p>Loop diuretic; e.g. frusemide 40 – 120mg IV with IV fluids to cover for the diuresis.</p>	<p>30 – 120 minutes</p>	<p>Enhanced renal excretion of K⁺ (Potassium losing diuretic)</p>
<p>Polystyrene sulfonate salt; e.g. calcium or sodium resonium 30 – 45g</p>	<p>1 – 3 hours</p>	<p>Ion exchange resin that bind K⁺ and enhances GI elimination</p>

PO/PR		
Dialysis; K ⁺ free IHD, SLED, CRRT or peritoneal dialysis	Applied for several hours, but rapidity of effect related to blood flow rate	Transfilter, or transperitoneal, K ⁺ removal

Rationale:



Description

Bradyarrhythmia with a rate of approximately 60 – 65bpm

Absent / Flat P-waves (Black ellipses)

Broad QRS complexes with bizarre morphology (Blue ellipses)

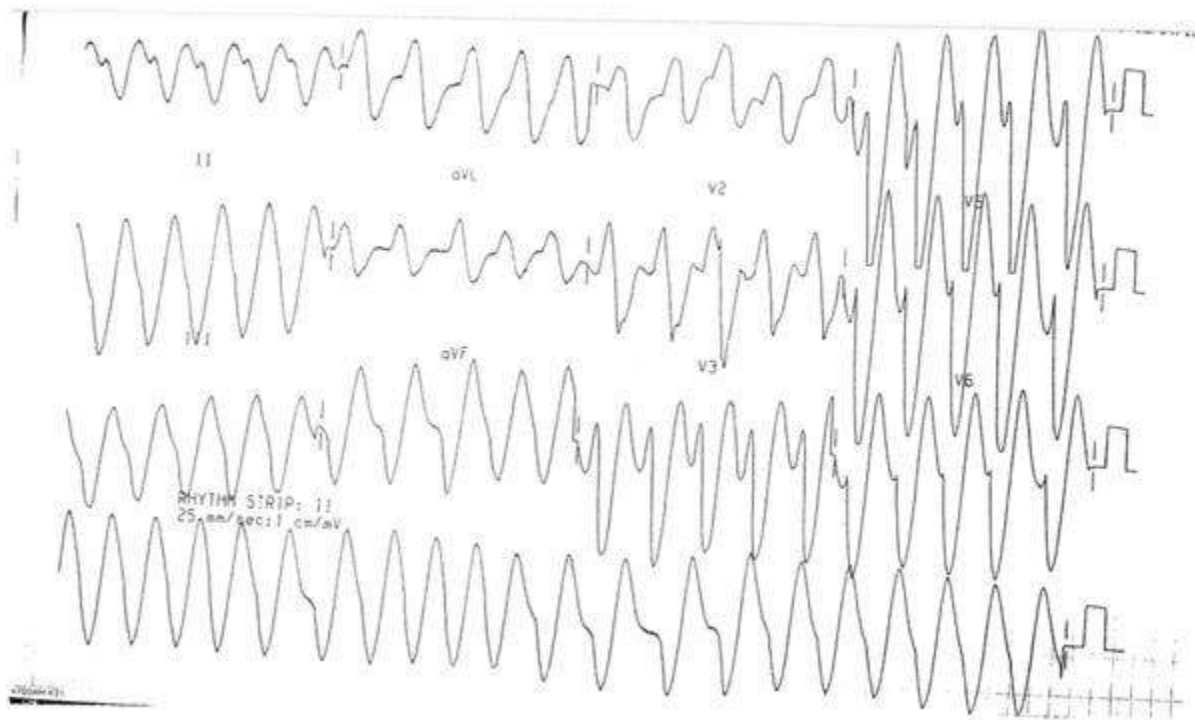
Tall, peaked T-waves (Pink ellipses)

Approaching sinusoidal waveform, which is a pre-asystolic rhythm

ECG – Case 16

Question:

A patient with a history of hypertension, depression and gout presents to the emergency department. Outline your management of the condition responsible for the following ECG.

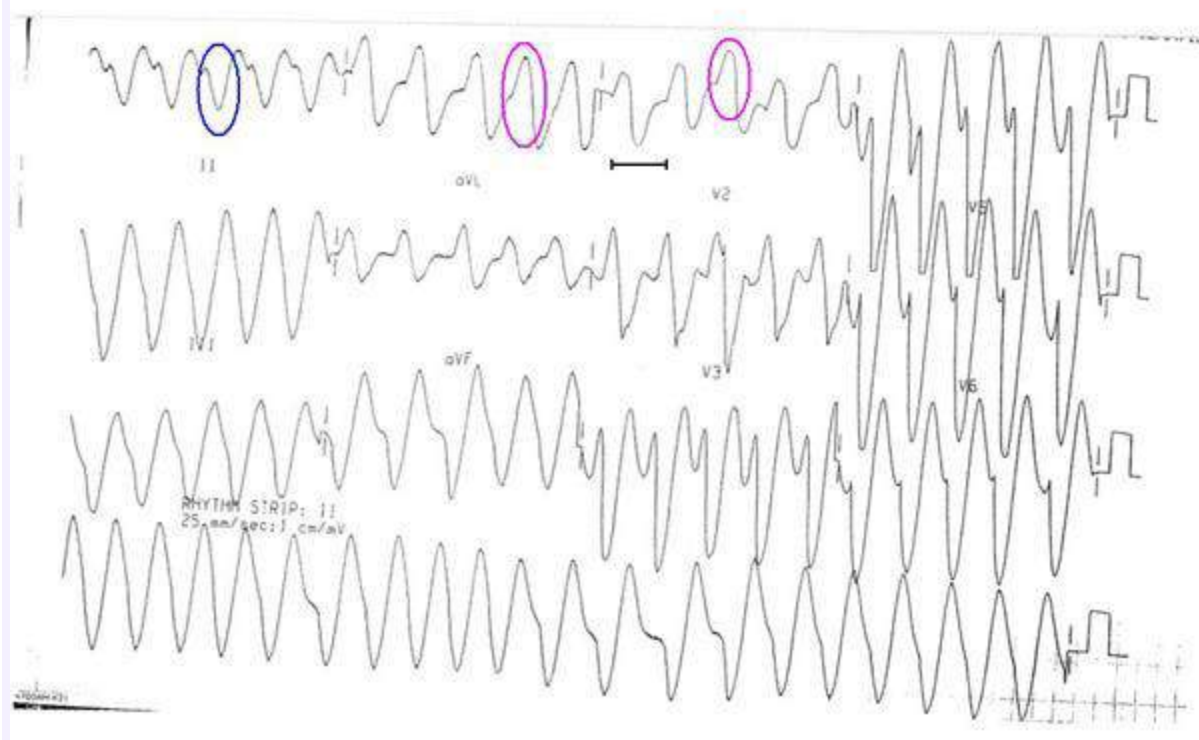


Answer:

Diagnosis = Tricyclic antidepressant toxicity

Management

10. Support oxygenation and ventilation
11. Support blood pressure with IV crystalloid. If significant hypotension, 1 – 2mEq/kg NaHCO₃ is indicated. If refractory, use noradrenalin IV infusion.
12. Treat arrhythmias (high risk if QRS >0.1s) with 1 – 2mEq/K NaHCO₃ IV, 1mg/kg Lignocaine IV and synchronised cardioversion.
13. Treat seizures (high risk if QRS >0.1s) with benzodiazepines. The role of phenytoin is controversial and not recommended by some authors.
14. 1 – 2mEq/K NaHCO₃ IV rapidly narrows the QRS complex width and reduces the risk of arrhythmias
15. Once the airway is secured, consider gastric lavage as the antimuscarinic effect often results in delayed gastric emptying and absorption of further drug can therefore be reduced
16. Consider using 20% intralipid IV, as TCADs are lipophilic
17. Full monitoring while QRS remains prolonged
18. If intentional, will require psychiatric review, once acute toxicity has resolved



Description

Broad complex, regular tachycardia

Prolonged QT interval (Black bar)

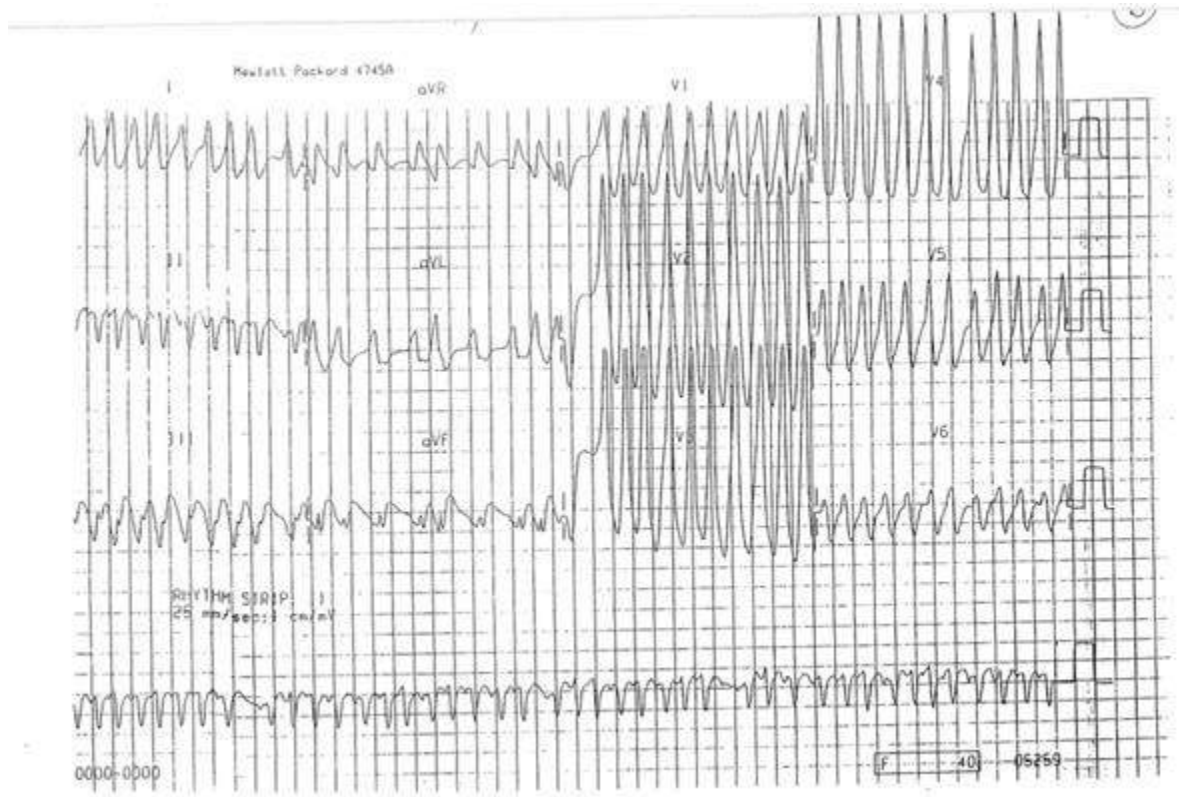
Deep S-wave in lead I (Blue ellipse)

Prominent R-wave in aVL or V1 (Pink ellipse)

ECG – Case 17

Question:

What are the treatment options for a normotensive patient with this ECG?



Answer:

Diagnosis = Wolff-Parkinson-White syndrome in atrial fibrillation with ultrarapid ventricular response

Treatment options:

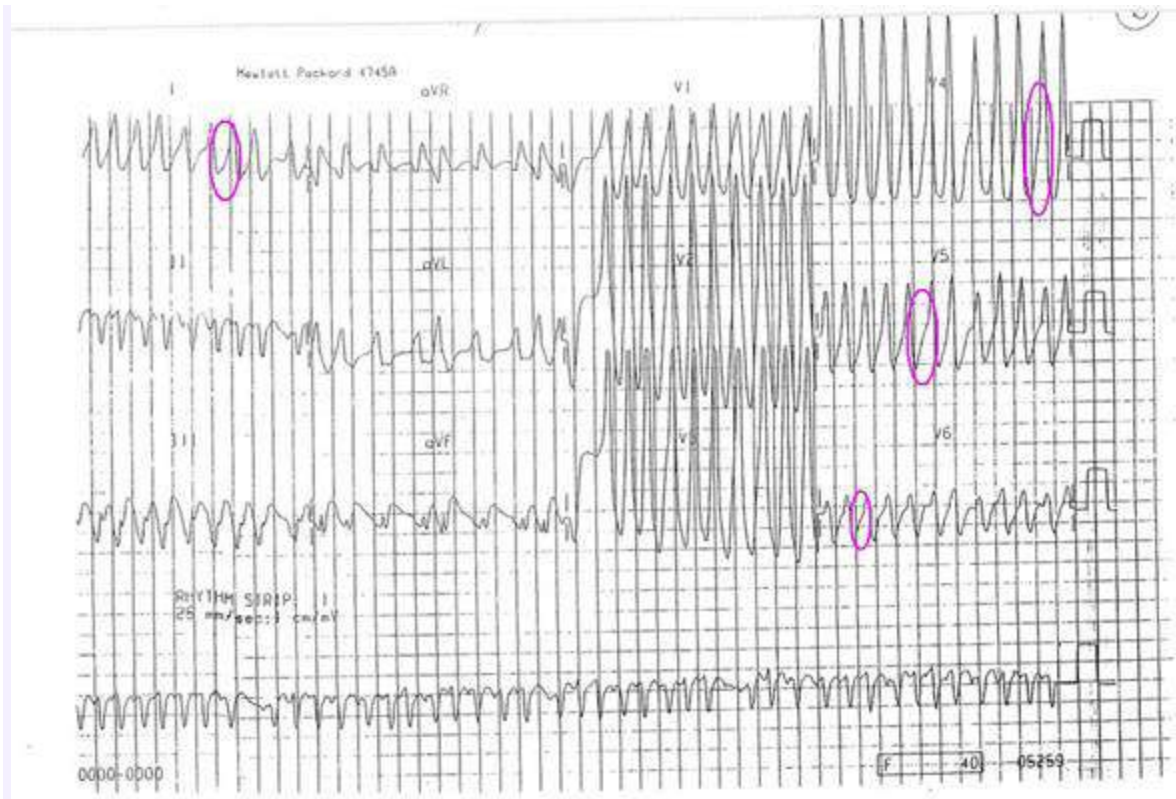
Pharmacological

4. Amiodarone
5. Procainamide
6. Flecainide

Electrical

2. Synchronised cardioversion

Avoid AV node blockers (verapamil, digoxin and β -blockers) which may accelerate the tachyarrhythmia



Description

Irregular tachycardia at approximately 300bpm

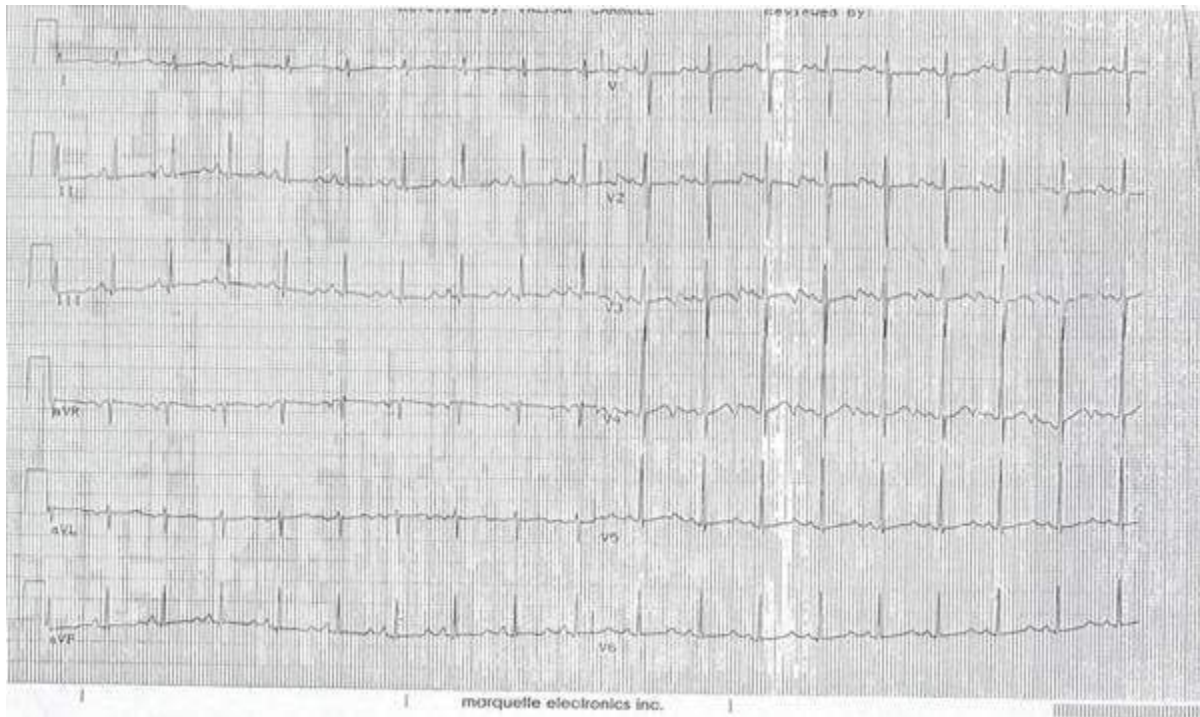
Slurred upstroke at the start of the QRS complex visible in several leads (Pink ellipses)

Difficult to determine the type (A-E) and therefore the location of the accessory tract, due to the rapidity of the tachycardia on this ECG. Obtaining a repeat ECG after the rate has been slowed would help

ECG – Case 18

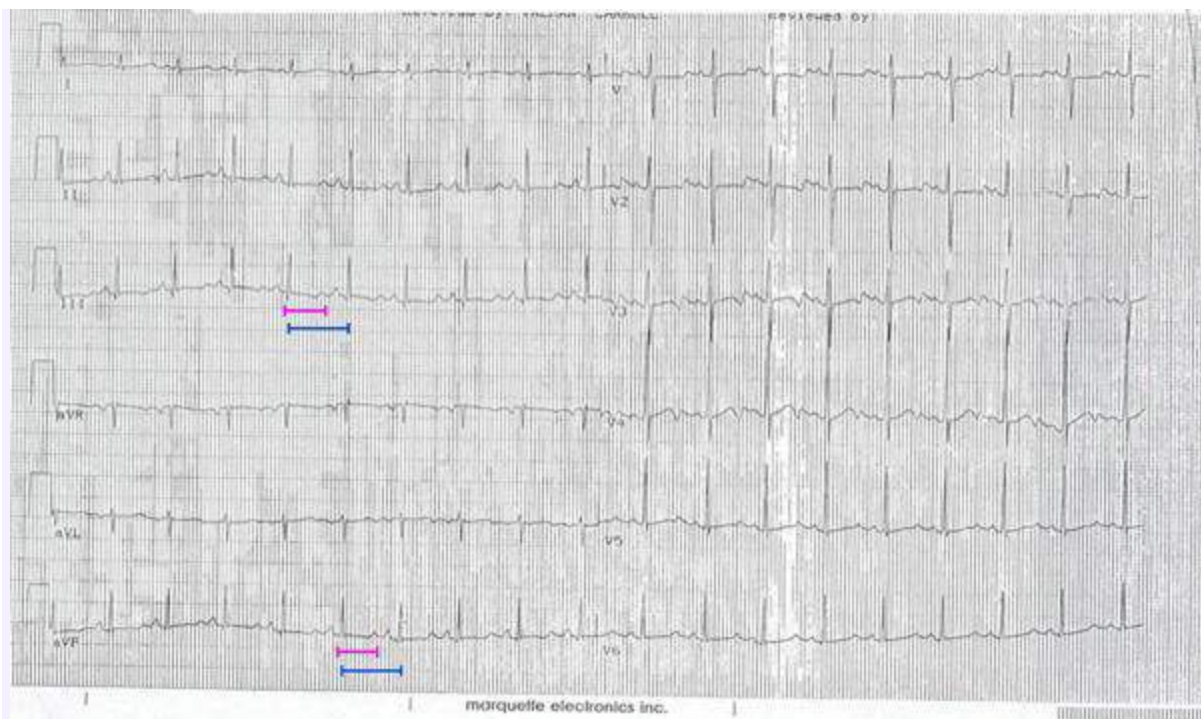
Question:

List 7 causes of the following ECG appearance.



Answer:

- Electrolyte disturbances – hypoMg, hypoK, hypoCa
- Medication – Class Ia, Ic and III antiarrhythmics, macrolides, azole antifungals, antipsychotics, antidepressants, antihistamines
- Endocrinopathies – hypothyroidism, pheochromocytoma
- Cardiac disease – AMI, myocarditis
- Intracranial pathologies – ICH, CVA
- TPN
- Congenital conditions – Romano-Ward syndrome, Jervelle-Lang-Nielson syndrome



Description

If numerical data is available at the top of the ECG, one of the few to be taken on faith is the QTc, as it is tricky to calculate Bazett's formula under exam conditions. The normal QTc is < 440mSec. Alternatively, visually checking to see if the QT interval (Pink bar) appears to occupy more than half of the R-R interval (Blue bar) is a valid estimate of prolongation

Laboratory data case

These questions can provoke significant anxiety for candidates, especially for those of us who feel intimidated by maths. However, if practiced, these questions can be answered quickly, yielding valuable points and creating extra time for answering less cut and dry questions. In reality, there are only a few regularly used calculations and many cases follow common patterns that can be recognised once you have seen them a few times.

For anyone wishing to practice these types of questions, some good resources include:

- Mark Finnis' Biochemistry data set - http://www.icuadelaide.com.au/ss_finnis_notes.html
- "Data Interpretation in Critical Care Medicine"; Bala Venkatesh, T.J. Morgan, Chris Joyce; Elsevier
- "Practical intensive care medicine: *Problem solving in the ICU.*" Charlie Corke. Butterworth-Heinemann, 2nd Ed.
- Crit-IQ - <http://www.crit-iq.com.au>.
- PACT (Patient-centred Acute Care Training) - The European Society of Intensive Care Medicine eLearning program, available at <http://www.esicm.org/>. Click on the "Education" tab and choose "PACT Programme" from the drop down menu.

Additionally, MRCP preparation books and online sources are fairly plentiful, although less tailored towards the ICU exam format.

Tips for the laboratory data questions

- Read the lead-in scenario carefully. Every word is carefully placed in the stem; not to trap you, but rather to guide you towards a limited differential list. Often you can get a feeling from the stem for what diagnosis the subsequent numbers are going to result in.
- Don't provide long-winded explanations in your answers. Succinct bullet points will buy you some time and gain you the same marks, along with a degree of credit with the examiner who has to wade through thirty or so scripts. (Note: In the cases that follow, a fuller answer than might be required by a question in the exam is provided, in order to explain the thought processes that derive the answer.)
- Try to quantify deficits; e.g. mild, moderate, severe, life threatening. It suggests clarity and your ability to prioritise; both important consultant qualities.
- Some of the calculations used have several variations; e.g. calculated osmolality, anion gap, corrected Na^+ in hyperglycaemia. Use whichever one you are most comfortable with.
- If an extra value seems to have appeared amongst otherwise routine data (e.g. iCa^{2+} , uric acid, WBC differential), question why it is there, as it is unlikely to be extraneous.

Useful calculations

- Calc Osm = $(2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- Osmolar Gap = Measured Osm – Calc Osm; normal < 10 mOsm/kg
- AG = $(\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO})$. Normal 6-15 mmol/L
- Corrected Na = $\text{Na} + (\text{Glucose}/3)$
- Corrected Ca = $\text{Ca} + 0.02(40 - \text{albumin})$

Acid-base corrections:

Acid-base disorder	Rule (kPa)	Rule (mmHg) *
Primary Acute respiratory acidosis	HCO_3^- increase 1 mmol/L per 1.3 kPa rise in PaCO_2 above 5 kPa (up to 30 mmol/L)	HCO_3^- increases 1 mmol/L per 10 mmHg rise in PaCO_2 above 40 mmHg (up to 30 mmol/L)
Primary Chronic respiratory acidosis	HCO_3^- increases 4 mmol/L per 1.3 kPa rise in PaCO_2 above 5 kPa (up to 36 mmol/L)	HCO_3^- increases 4 mmol/L per 10 mmHg rise in PaCO_2 above 40 mmHg (up to 36 mmol/L)
Primary Acute respiratory alkalosis	HCO_3^- decreases 2 mmol/L per 1.3 kPa fall in PaCO_2 below 5 kPa	HCO_3^- decreases 2 mmol/L per 10 mmHg fall in PaCO_2 below 40 mmHg
Chronic respiratory alkalosis	HCO_3^- decreases 5 mmol/L per 1.3 kPa fall in PaCO_2 below 5 kPa	HCO_3^- decreases 5 mmol/L per 10 mmHg fall in PaCO_2 below 40 mmHg
Primary metabolic acidosis	$\text{PaCO}_2 \text{ (kPa)} = 0.2(\text{HCO}_3^-) + 1$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.	$\text{PaCO}_2 = (1.5 \times \text{HCO}_3^-) + 8$ PaCO_2 should be within 5 mmHg of the number denoted after the decimal point in the pH (down to a PaCO_2 10) e.g. pH 7.10 – PaCO_2 should be 10 Alternatively, expected $\text{PaCO}_2 = (\text{HCO}_3^- \times 1.5) + 8$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis.

		If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.
Primary metabolic alkalosis	$\text{PaCO}_2 \text{ (kPa)} = 0.12(\text{HCO}_3) + 1.2$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.	$\text{PaCO}_2 = (0.9 \times \text{HCO}_3) + 9$ PaCO_2 should be within 5mmHg of the number denoted after the decimal point in the pH (up to a PaCO_2 60) e.g. pH 7.6 – PaCO_2 should be 60 Alternatively, expected $\text{PaCO}_2 = (\text{HCO}_3 \times 0.9) + 9$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.

You should try and memorise some of the more common reference ranges for laboratory data, mostly as it saves time when attempting the answer. However, it is recognised that hospitals often have varying reference ranges, based on the equipment calibration, so "normal" values are usually provided in exams. A set of reference ranges is provided for the laboratory values used in the following questions. Click on reference ranges if you need a reminder.

Lab data – Case 1

Question:

A 59 year old lady on the ward has recently been treated for painful active rheumatoid arthritis. While awaiting completion of her discharge planning, a MET call is put out for a witnessed collapse that occurred when she got up to use the bathroom. The first intravenous volume bolus has not improved her blood pressure. What therapy would you consider next?

Urea 11.2mmol/L	Ca 2.37mmol/L
Creatinine 91 $\mu\text{mol/L}$	Mg 0.87mmol/L
Na 127mmol/L	PO4 1.01mmol/L
K 5.9mmol/L	
Cl 96mmol/L	Albumin 36g/L
TCO2 21mmol/L	

BSL 4.1mmol/L

Serum Osm 273mOsm/L

Urine Osm 315mOsm/L

Urine Na 47mmol/L

Urine Cl 21mmol/L

Answer:

Therapy: 100mg Hydrocortisone IV or 4mg Dexamethasone IV and then reinstate a regular oral dose of prednisone. Using dexamethasone will not preclude performing a short synacthen test.

Rationale:

Diagnosis: Addisonism secondary to acute steroid withdrawal

Recent steroid therapy is implied by management of active painful rheumatoid arthritis. The postural hypotensive episode and the blood pressure not responding as expected to a volume challenge is consistent with adrenal insufficiency, as is the hypoosmolar hyponatremia with elevated K, urine Na > 20mmol/L, low blood glucose and normal anion gap metabolic acidosis, using the TCO₂ as a surrogate for HCO₃ .

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 2

Question:

A 22 year old construction worker, who was admitted to the ward two days ago for management of an oblique left tibio-fibular shaft fracture, has been requiring increasing doses of opiate analgesia, despite immobilisation of the injured limb, and today was noted to have a reduced urine output. Outline your initial management.

Urea 24.5 mmol/L	Ca 2.03 mmol/L
Creatinine 266 µmol/L	Mg 0.98 mmol/L
Na 137mmol/L	PO4 1.33 mmol/L
K 6.0 mmol/L	Albumin 39 g/L
Cl 105 mmol/L	
TCO2 20 mmol/L	CK 43,000 U/L
BSL 8.3 mmol/L	Bilirubin 9µmol/L
	AST 246 U/L
	ALT 89 U/L
	GGT 43U/L
	ALP 82 U/L
	LDH 603 U/L

Answer:

Therapy:

- IV hydration with a crystalloid, aiming for a urine output of 1.5 – 2 ml/kg/hr
- Urinary alkalinisation with 0.5mEq/kg NaHCO₃ in 1000mls 0.9% saline, or 1mEq/kg NaHCO₃ in 1000mls 5% dextrose, at 100mls/hr, targeting a urinary pH of greater than 7.0
- The use of diuretics and mannitol to enhance elimination is controversial due to the potential for intravascular volume depletion and an enhanced risk of renal failure.
- Dialysis may be required if acute renal failure ensues, particularly with the hyperkalaemia
- If the limb has been immobilised with a full cast, split the cast to release any pressure due to swelling of the injured limb
- Advocate for theatre to perform a fasciotomy and debridement of any necrotic muscle
- Analgesia

Rationale:

Diagnosis: Rhabdomyolysis due to compartment syndrome

Predisposing injury for compartment syndrome with pain out of proportion to the apparent injury. Acute renal failure, likely due to myoglobinuria, as the raised CK and LDH suggests muscle cell destruction. Myolysis is also suggested by the raised K⁺, PO₄, Mg²⁺ and AST. The low Ca²⁺ is due to sequestration by the damaged tissue, but is rarely clinically significant and can be used as a marker for recovery.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 3

Question:

A 48 year old gentleman is brought to the emergency department via ambulance. He was found in park land, confused. His observations are as follows: HR 107bpm, BP 98/56mmHg, RR 26bpm, SpO₂ 94% RA, Temp 35.6C. What further test would you request?

Urea 11.8mmol/L	Ca 2.05mmol/L
Creatinine 109 µmol/L	Mg 0.72mmol/L
Na 129mmol/L	PO ₄ 1.35mmol/L
K 5.6mmol/L	Albumin 31g/L
Cl 86mmol/L	Uric acid 0.52 mmol/L
TCO ₂ 16mmol/L	
BSL 4.3mmol/L	
Serum Osm 298mOsm/kg	
Urine Osm 387mOsm/kg	
Urine Na 8mmol/L	

Answer:

Test requested: Serum ethanol and methanol level

Rationale:

Diagnosis: Alcohol toxicity

Young to middle aged adult found with an altered level of consciousness in a park usually suggests trauma or toxicology. A hyperosmolar hyponatraemia with a wide osmolar gap and acute renal impairment due to pre-renal deficit is consistent with alcohol toxicity. The raised anion gap metabolic acidosis is due to products of alcohol metabolism and acute renal failure. Hypoglycaemia may be an acute alcohol effect, or, in addition with the low albumin, may reflect malnutrition due to chronic alcoholism.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

-

• Lab data – Case 4

• Question:

- A 53 year old obese gentleman, with a past medical history that includes ischaemic heart disease, and hypertension, presents to the emergency department with confusion and is combative. He is afebrile, with the following observations: HR 113bpm, sinus, BP 108/74mmHg, RR 28bpm, SpO2 96% RA. What is the diagnosis and what therapy would you initiate?

Urea 16.2mmol/L	Serum Osm 352 mOsm/kg
Creatinine 118 $\mu\text{mol/L}$	Urine Osm 476 mOsm/kg
Na 146 mmol/L	Urine Na 32 mmol/L
K 3.8 mmol/L	
Cl 115 mmol/L	Ca 2.56 mmol/L
TCO2 20 mmol/L	Mg 0.76 mmol/L
BSL 36.9 mmol/L	PO4 1.53 mmol/L
	Albumin 48 g/L

-

• Answer:

- Diagnosis: Hyperosmolar hypernatraemic non-ketotic state (HHNS / HONK)
- Therapy:
 - IV rehydration with crystalloid, often requiring an 8 – 10 litre replacement over the next 48 – 72 hours. The onset of HHNS is often subacute, so correction of the deficit should mirror this. Otherwise a rapid fall in the serum Na^+ may result in cerebral oedema.
 - IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts

- K⁺ replacement may be required with the insulin infusion
- Search for and treat the precipitant; commonly sepsis, an acute coronary syndrome or a cerebrovascular event.
- These patients are at higher risk of thromboembolic events, due to the hyperosmolarity, and should receive anticoagulant prophylaxis unless contraindicated.
-
- **Rationale:**
- An obese patient in his 50's with cardiovascular risk factors with a blood glucose that is very high. HHNS hyperglycaemia is often higher than DKA hyperglycaemia. The corrected sodium is high. Don't be put off by the mild metabolic acidosis that is often present. The deranged observations and raised albumin are a reflection of the extreme dehydration, as these patients often have a volume deficit of the order of 8 to 10 litres
- Calc Osm = (2xNa) + Urea + Glucose
- Osmolar Gap = Measured Osm – Calc Osm; normal < 10mOsm/kg
- AG = (Na) - (Cl + HCO₃ or TCO₂). Normal 6-15mmol/L
- Corrected Na = Na + (Glucose/3)
- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 5

Question:

A 34 year old lady, who was admitted with a fever, altered behaviour and a rapid decrease in level of consciousness necessitating invasive airway support, has been noted to have a urine output consistently greater than 150mls/hr. A lumbar puncture is performed and the result, along with her biochemistry is displayed below. What is her diagnosis?

Urea 13.3mmol/L	<u>Lumbar puncture</u>
Creatinine 125µmol/L	Microscopy
Na 152mmol/L	RBC 3 x 10 ⁹ /ml
K 3.8mmol/L	Polymorph 32 x 10 ⁹ /ml
Cl 118mmol/L	Mono 10 x 10 ⁹ /ml
TCO ₂ 23mmol/L	No organisms seen
	Glucose 4.4mmol/L (2.5 – 5.5mmol/L)
Serum Osm 319mOsm/kg	Protein 0.78g/L (0.15 – 0.45g/L)
Urine Osm 236mOsm/kg	

Urine Na 74mmol/L	Cryptococcal Atg negative
Ca 2.41mmol/L	
Mg 0.96mmol/L	
PO4 1.10mmol/L	
Albumin 44g/L	
BSL 6.2mmol/L	
Uric acid 0.61 mmol/L	

Answer:

Diagnosis: Cranial diabetes insipidus secondary to viral encephalitis

Rationale:

Fever with altered behaviour and a rapid decline in conscious level is suggestive of an infective encephalitis, usually viral. The LP biochemistry (raised protein with relatively preserved serum to CSF glucose ratio) and cell count are supportive and a viral PCR should be requested.

A hyperosmolar hypernatraemia with inappropriately hypoosmolar urine is typical of diabetes insipidus. The setting of an intracranial pathology directs you to cranial DI. Additionally, an elevated serum uric acid also supports cranial over nephrogenic DI.

The pre-renal urea to creatinine ratio and raised serum albumin suggest an intravascular volume deficit and is consistent with the main diagnosis

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 6

Question:

A 36yo lady is admitted to the ward with an exacerbation of her ulcerative colitis. She takes prednisone and azathioprine. She is tachycardic and hypotensive. Her blood results return as follows and the team junior medical officer has requested assistance with managing her SIADH. What would you suggest?

Urea 13.4mmol/L	Serum Osm 268mOsm/kg
Creatinine 101µmol/L	Urine Osm 423mOsm/kg
Na 122mmol/L	Urine Na 4mmol/L
K 3.6mmol/L	Ca 2.15mmol/L
Cl 92mmol/L	Mg 0.77mmol/L
TCO2 19mmol/L	PO4 0.94mmol/L
BSL 7.6mmol/L	Albumin 31g/L

Answer:

Advice:

- Resuscitate her shocked state with crystalloid
- Ongoing fluid replacement over the next 48 hours should correct her hyponatremia gently
- Treat her acute ulcerative colitis exacerbation: 5-aminosalicylate + hydrocortisone or prednisone ± azathioprine

Rationale:

Diagnosis: Extra-renal sodium loss, likely secondary to GI loss due to the patient's exacerbation of ulcerative colitis

Her haemodynamic status suggests a volume deficit, which when combined with her biochemistry, produces a hypovolaemic, hypoosmolar hyponatraemia with avid renal Na retention. This is not consistent with a picture of SIADH. The admission reason suggests that there is significant diarrhoea, which is the most likely source of her extra-renal Na loss. There is a normal AG metabolic acidosis in the presence of hypokalaemia, consistent with GI bicarbonate loss

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L

- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 7

Question:

A 45 year old gentleman is brought to the emergency with increasing dyspnoea. His family have noted that his behaviour recently has been unusual and admit that he is prone to episodic alcohol binges. On examination, he is tachypnoeic and has a distended abdomen.

What is the likely diagnosis and how would you grade it?

Urea 4.1mmol/L	FiO2 28%
Creatinine 72µmol/L	pH 7.46
Na 129mmol/L	PCO2 34mmHg / 4.53 kPa
K 2.9mmol/L	PO2 88mmHg / 11.73kPa
Cl 92mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 6.4mmol/L	Hb 93g/dL
	MCV 107fl (normal 78-101 fl)
Ca 1.85mmol/L	MCH 27pg (normal 25-35 pg/cell)
Mg 0.68mmol/L	WBC 8.1x10 ⁹ /L
PO4 0.75mmol/L	PLT 105x10 ⁹ /L
Albumin 26g/L	
	aPTT 39s
Bilirubin 6µmol/L	PT 22s
AST 33U/L	INR1.5
ALT 42U/L	

GGT 57U/L

ALP 94U/L

Serum Osm 270mOsm/kg

Urine Osm 224mOsm/kg

Urine Na 7mmol/L

How would you interpret the results of the abdominal paracentesis and how do they affect your choice of therapy?

Ascitic fluid

Glucose 2.3 mmol/L

Albumin 54 g/L

pH 7.32

WBC 577 $\times 10^9$ /ml

Polymorphs 444 $\times 10^9$ /ml

RBC 89 $\times 10^9$ /ml

Gram stain: Polymorphs ++

Culture: Pure growth of Enterobacter species

Answer:

Diagnosis: Hepatic encephalopathy due to spontaneous bacterial peritonitis on a background of alcoholic cirrhosis, Childs-Pugh Grade B. The identification of an enterobacter species, an ESCAPM organism, narrows the available choice of antibiotics to gentamicin or a carbapenem.

Rationale:

A history of alcoholism. The distended abdomen is probably ascites. Hypoosmolar hyponatraemia with a low urea (which suggests he is not hypovolaemic nor in renal failure and has a decreased liver synthetic function), plus low K

(due to the impaired aldosterone metabolism), low albumen and prolonged PT and INR (due to impaired liver synthetic function). The serum and urine osmolarities also suggest he is not hypovolaemic and would not be consistent with an SIADH, thus favouring a hypervolaemic hypoosmolar hyponatraemia, such as cirrhosis. The respiratory alkalosis and mild A-a gradient would be consistent with limited diaphragmatic movement and basal atelectasis due to ascites or a metabolic encephalopathy. The LFTs need not be grossly disturbed, especially if there is little functional hepatic tissue remaining.

ESCAPM agents are identified by the presence of the Amp-C gene, which codes for an inducible β -lactamase that results in apparent in vitro sensitivity, but inevitable in vivo β -lactam resistance.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal $6-15 \text{ mmol/L}$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Child's-Pugh grading			
Score	1	2	3
Bilirubin ($\mu\text{mol/L}$)	<34	34-51	>51
Albumen (g/L)	>35	28-35	<28
PT (+ secs)	1-3	3-6	>6
Ascites	0	Grade I	Grade II
Encephalopathy	0	1-2	3-4
(West-Haven grade)			

5-6 = Child-Pugh A ® Too early for liver transplant referral

7-9 = Child-Pugh B ® Discuss with transplant team

10-15 = Child-Pugh C ® Refer to transplant team for assessment

Lab data – Case 8

Question:

A 78 year old gentleman is on SIMV with PEEP = 10 and Pmean = 18mmHg, for lobar pneumonia. He is on $0.06 \mu\text{g/kg/min}$ of noradrenalin to maintain a MAP of 65mmHg. His urine output averages 40ml/hr. The nurse is concerned about the hyponatraemia. What is causing it?

Urea 7.6 mmol/L	Bilirubin $9 \mu\text{mol/L}$
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Creatinine 71 μ mol/L	AST 39 U/L
Na 123mmol/L	ALT 36 U/L
K 4.2mmol/L	GGT 62 U/L
Cl 89mmol/L	ALP 101 U/L
TCO2 23mmol/L	
BSL 7.3mmol/L	Serum Osm 275mOsm/kg
Ca 2.26mmol/L	Urine Osm 461mOsm/kg
Mg 0.88mmol/L	Urine Na 39mmol/L
PO4 1.13mmol/L	
Albumin 34g/L	

Answer:

Diagnosis: SIADH

Rationale:

Hypoosmolar hyponatraemia with an inappropriately high urine osmolarity for the low serum osmolarity and a urine Na > 20mmol/L is almost enough by itself in an exam. A normal urea and creatinine and reasonable urine output suggest he is euvolaemic. The otherwise normal EUC, BSL, LFTs and Ca²⁺ reduce the likelihood of a renal, liver or adrenal cause, as required for the diagnosis of SIADH. The noradrenaline dose is minimal. The pneumonia is the likely precipitant of the SIADH.

If there were clinical clues that the patient was hypovolaemic (e.g. dry mucous membranes, lack of tissue oedema, lack of pulmonary oedema, tachycardia, hypotension) then consider a salt wasting syndrome, cerebral or renal, which may be quite similar biochemically, but are managed very differently (fluid restriction for SIADH, fluid replacement for salt wasting syndromes)

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L

Lab data – Case 9

Question:

A 53 year old lady has been in your ICU for 13 days following resolution of community acquired pneumonia. Having undergone aggressive early goal directed therapy by the unit registrar for her initial septic shock, she has been slow to wean from invasive mechanical ventilation, due to a persistent FiO₂ and PEEP requirement, despite the resolution of her inflammatory markers several days earlier. Her observations are: HR 92bpm sinus, BP 106/73 (no vasopressor), RR 28bpm, SpO₂ 95%, Temp 36.7°C, Urine output 60 – 120ml/hr. The nurse is concerned about the ongoing need for potassium replacement. What is the likely cause?

Urea 12.7mmol/L	pH 7.47
Creatinine 99µmol/L	PCO ₂ 46mmHg / 6.13 kPa
Na 124mmol/L	PO ₂ 92mmHg / 12.27 kPa
K 3.1mmol/L	HCO ₃ 29mmol/L
Cl 88mmol/L	SBE +3
TCO ₂ 32mmol/L	
BSL 8.3mmol/L	
Serum Osm 273mOsm/kg	
Urine Osm 325mOsm/kg	
Urine Na 34mmol/L	

Answer:

Diagnosis: Potassium-losing diuretic (e.g. frusemide, which is commonly used in ICUs)

Rationale:

Hypoosmolar hyponatraemia with hypovolaemia, suggested by the upper limit of normal HR and lower limit of normal BP in the presence of a volume contraction hypokalaemic metabolic alkalosis. The urine Na > 20mmol/L suggests renal sodium loss. The differential includes a loop diuretic or a salt wasting syndrome. The eager initial volume

resuscitation of her septic shock (EGDT), along with any sepsis related non-cardiogenic pulmonary oedema, is the likely cause for the slow ventilator wean and is being treated with a loop diuretic, resulting in the above biochemistry. It is also possible that the metabolic alkalosis that has been induced by the loop diuretic is also hindering the weaning process and it could be ameliorated by some acetazolamide.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L

Lab data – Case 10

Question:

A 25 year old gentleman is admitted to your ICU heavily sedated, intubated and ventilated following a fall from construction scaffolding. He sustained rib fractures and significant head injury. He has just returned from the operating theatre, where a decompressive craniectomy was performed. What is your explanation for his initial blood picture?

Urea 7.3mmol/L	Serum Osm 334mOsm/kg
Creatinine 87µmol/L	Urine Osm 417mOsm/kg
Na 151mmol/L	Urine Na 32mmol/L
K 2.6mmol/L	
Cl 116mmol/L	Ca 2.25mmol/L
TCO2 26mmol/L	Mg 0.87mmol/L
	PO4 0.96mmol/L
BSL 8.1mmol/L	Albumin 32g/L

Answer:

Diagnosis: Recent mannitol therapy

Rationale:

A traumatic brain injury with management suggesting there have been difficulties maintaining an appropriate ICP. Hyperosmolar hyponatraemia with a widened osmolar gap $> 10 \text{mOsm/L}$, consistent with recent mannitol therapy. The hypokalaemia suggests that the sedating agent may be thiopentone

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/L}$

Lab data – Case 11

Question:

A 59 year old lady is admitted to your ICU, having had several seizures at home. She is markedly icteric and has been intubated in the emergency department. Outline your management strategy for the first 24 hours of her admission.

Urea 18.7mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.27
Na 127mmol/L	PCO2 24mmHg / 3.20 kPa
K 3.2mmol/L	PO2 116mmHg / 15.47 kPa
Cl 87mmol/L	HCO ₃ 16mmol/L
TCO2 21mmol/L	SBE -9
BSL 2.1mmol/L	Hb 86g/dL
Ca 1.99mmol/L	MCV 111fl (normal = 78-101 fl)
Mg 0.68mmol/L	MCH 102pg (normal = 25-35 pg/cell)
PO4 0.62mmol/L	WBC $12.1 \times 10^9/\text{L}$
Albumin 28g/L	PLT $117 \times 10^9/\text{L}$
Bilirubin 134µmol/L	aPTT 41s
AST 928U/L	PT 25s
ALT 342U/L	INR 1.7

GGT 257U/L

ALP 184U/L

Serum Osm 279mOsm/kg

Urine Osm 194mOsm/kg

Urine Na 13mmol/L

Answer:

Management:

- Correct the hypoglycaemia with 50% Dextrose initially and then an ongoing 5 – 10% dextrose infusion until stable normoglycaemia
- Correct any hypovolaemia or dehydration
- Advocate for an urgent upper GI endoscopy to identify bleeding ulcer disease or varices
- Start IV octreotide 50µcg bolus and then 50µcg/hr infusion
- Start IV pantoprazole 80mg bolus and then 10mg/hr infusion
- Give IV vitamin K 5mg. Give FFP also if there is evidence of active bleeding.
- Start lactulose – PR prior to the endoscopy and via the nasogastric tube afterwards.
- Exclude sepsis, including spontaneous bacterial peritonitis
- Minimise opiate and benzodiazepine use during her period of intubation in order to avoid a prolonged sedation wean.

Rationale:

Diagnosis: Alcohol-induced acute on chronic liver failure with encephalopathy, hypoglycaemia and a likely upper GI bleed

Moderate transaminitis with an AST : ALT ratio > 2, suggests an alcoholic hepatitis. The history, level of transaminitis and hyperbilirubinaemia suggest an acute process. The hypoglycaemia, hypoalbuminaemia and prolonged PT / INR suggest diminished hepatic reserve and synthetic function and an underlying chronic dysfunction, such as cirrhosis. In addition, the low creatinine relative to the urea suggests a low muscle mass and possible malnutrition. The anaemia may be acute and, with the elevated urea out of proportion to the creatinine, may be the result of an upper GI bleed, either ulcerative or variceal. It may also reflect the alcoholic background – low Hb with raised MCV. The raised anion gap metabolic acidosis could be the result of a lactic acidosis from impaired liver function, an acute pancreatitis, an alcoholic or starvation ketosis or alcohol toxicity (less likely with the normal osmolar gap).

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L

- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 12

Question:

A 37 year old lady is admitted to the maternity ward at 34 weeks gestation (G2P1) with upper abdominal discomfort and a sensation that her shoes and rings are too tight. She has not attended any ante-natal care. On examination she has a fundal height of 35cm and six beats of clonus. Her urine appears dark. Her observations are as follows, HR 102bpm sinus, BP 133/87mmHg, RR 18bpm, SpO2 100% on nasal prongs at 4L/min, Temp 37.1°C. What management conflicts do you face for this patient?

Urea 5.9mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.43
Na 132mmol/L	PCO2 32mmHg / 4.27 kPa
K 3.4mmol/L	PO2 121mmHg / 16.13 kPa
Cl 95mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 5.1mmol/L	Hb 94g/dL
Ca 2.14mmol/L	MCV 108fl (normal = 78-101 fl)
Mg 0.72mmol/L	MCH 37pg (normal = 25-35 pg/cell)
PO4 0.92mmol/L	WBC 12.3x10 ⁹ /L
Albumin 33g/L	PLT 125x10 ⁹ /L
Bilirubin 56µmol/L	aPTT 34s
AST 137U/L	PT 21s
ALT 144UI/L	INR1.4

GGT 108U/L

ALP 139U/L

Serum Osm 273mOsm/kg

Urine Osm 182mOsm/kg

Urine Na 9mmol/L

Urine protein + + +

Answer:

Conflicts:

1. The patient is demonstrating features of evolving pre-eclampsia and HELLP syndrome. However, at 34 weeks gestation, foetal lung maturity is underdeveloped and a dose of dexamethasone 24 hours prior to delivery is desirable. Providing this period without excessive risk to the mother's health is a delicate timing issue.
2. Operative intervention in the setting of an uncontrolled coagulopathy presents an increased bleeding risk. The blood products used to correct the coagulopathy have a higher than usual risk of precipitating pulmonary oedema in this population of patients.
3. Once in the ICU, there is often a conflict of interest between supporting renal perfusion with fluids and precipitating pulmonary oedema. Both are transient, but most centres give preference to preventing pulmonary oedema and accepting a period of oliguria and deranged renal biochemistry.

Rationale:

Diagnosis: Preeclampsia / HELLP syndrome

Third trimester hypertension. The tachycardia and tachypnoea may simply reflect her third trimester status. More than 3 – 4 beats of clonus indicates hypertonicity and would be suggestive of preeclampsia in combination with her elevated blood pressure, peripheral oedema (tight rings and shoes) and proteinuria (the urine protein:creatinine ration suggests a proteinuria > 200mg/24hrs). The largely hepatitic LFTs suggest that there is more than just pre-eclampsia present and, in combination with the low platelets, indicates the presence of HELLP syndrome. Therefore, the upper abdominal discomfort may represent hepatic congestion, a subcapsular haematoma or a hepatic infarct. The raised bilirubin may be due to one or both of hepatitis or haemolysis. Remember that in the third trimester a mild compensated respiratory alkalosis is normal.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$
- Normal urine protein to creatinine ration is < 0.2

Lab data – Case 13

Question:

You are called to see a 29 year old woman, 33 weeks pregnant with a respiratory rate of 55/min. Her pregnancy has been complicated by persistent gestational nausea. She is otherwise healthy. The following pathology is available.

a) What is the likely diagnosis?

Day 1	Day 2
Urea $< 0.7 \text{ mmol/L}$	Urea $< 0.7 \text{ mmol/L}$
Creatinine $49 \text{ } \mu\text{mol/L}$	Creatinine $51 \text{ } \mu\text{mol/L}$
Na 135 mmol/L	Na 136 mmol/L
K 3.6 mmol/L	K 4.0 mmol/L
Cl 109 mmol/L	Cl 114 mmol/L
TCO ₂ 9 mmol/L	TCO ₂ 7 mmol/L
Urate 0.6 mmol/L	Osm 290 mOsm/kg
Hb 12.3 g/dL	Ca 2.35 mmol/L
WCC $15.9 \times 10^9/\text{L}$	Mg 0.79 mmol/L
PLT $256 \times 10^9/\text{L}$	PO ₄ 0.98 mmol/L
	Albumin 32 g/L
	Prot 73 g/L

	Bilirubin 14 µmol/L
	ALT 29 U/L
	AST 96 U/L
	GGT 34 U/L
	ALP 217 U/L
	Glucose 4.3 mmol/L
	pH 7.19
	PaCO ₂ 17 mmHg / 2.27 kPa
	PaO ₂ 124 mmHg / 16.53 kPa
	HCO ₃ 7 mmol
	SBE -19 mmol/L
	Lactate 0.69 mmol/L
	Hb 12.3 g/dL
	WCC 17.3 x10 ⁹ /L
	Plt 339 x10 ⁹ /L

b) She was subsequently treated appropriately. The following day, her morning bloods return What complication has occurred?.

Na 135 mmol/L	Ca 2.00 mmol/L
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K 3.5 mmol/L	Mg 0.85 mmol/L
Cl 110 mmol/L	PO4 0.36 mmol/L
TCO2 17 mmol/L	Albumin 21 g/L

Answer:

a) Starvation ketosis in pregnancy.

b) Refeeding syndrome.

Rationale:

This third trimester lady should have a mild compensated respiratory alkalosis as part of normal physiology. Instead she has a profound raised AG metabolic acidosis, in the absence of lactate, drugs or renal failure. That leaves ketosis. She is not diabetic and the blood glucose does not suggest a DKA. In fact the glucose is lower than expected, as is the albumen. Assuming she is not alcohol toxic, this leaves only starvation ketosis, which may be the result of her persistent gestational nausea. The raised WBC may be normal for gestation or a stress response to her illness

The low phosphate on day three suggests the appropriate therapy that she received included a carbohydrate load, resulting in refeeding syndrome.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

• Expected PaCO_2 for metabolic acidosis: mmHg = $(\text{HCO}_3 \times 1.5) + 8$; kPa = $0.2(\text{HCO}_3) + 1$

Lab data – Case 14

Question:

A 19 year old gentleman presents with abdominal pain and vomiting. He looks dehydrated and pale. He has no known medical history. His observations are as follows: HR 118bpm sinus, BP 104/62mmHg, RR 32bpm, SpO2 100%, Temp 37.8°C, Urine output 100 – 140ml/hr. How will you manage him initially?

Urea 17.8mmol/L	pH 7.13
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Creatinine 103µmol/L	PaCO ₂ 15 mmHg / 1.99 kPa
Na 130 mmol/L	PaO ₂ 124 mmHg / 16.53 kPa
K 3.0 mmol/L	HCO ₃ 7 mmol
Cl 87 mmol/L	SBE -21 mmol/L
TCO ₂ 11 mmol/l	Lactate 4.7 mmol/L
Osm 305mOsm/kg	Hb 13.1 g/dL
Ca 2.43 mmol/L	WCC 16.3 x10 ⁹ /L
Mg 0.54 mmol/L	Plt 532 x10 ⁹ /L
PO ₄ 1.06 mmol/L	
Albumin 43 g/L	
Bilirubin 11 µmol/L	
ALT 27 U/L	
AST 35 U/L	
GGT 28 U/L	
ALP 100U/L	
Glucose 24 mmol/L	
Lipase 68U/L	

Answer:

Management:

- IV rehydration with crystalloid, often requiring a 4 – 6 litre replacement over the next 24 – 48 hours, depending upon the rapidity of the onset of this illness.
- IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts
- K+ replacement will be required with the insulin infusion, given the total body K+ depletion evident
- Search for and treat the precipitant; commonly sepsis, trauma or drugs in a young person.

Rationale:

Diagnosis: DKA, as a first presentation of type I diabetes mellitus.

Moderate hyperglycaemia with a raised AG metabolic acidosis. The raised lactate is not enough to account for all of the AG and the deficit is made up by ketones. The patient shows evidence of hypovolaemia and dehydration clinically, yet is polyuric. The low potassium is a concern, given the level of acidosis, and suggests significant depletion of total body potassium reserves. This suggests that the patient has been unwell for some time and will need careful electrolyte management over the next 48 to 72 hours, including replacement of the magnesium.

The Hb may reflect dehydration. The WBC is non-specific and may be associated with infection as a precipitant of the DKA, or may be a stress response. The thrombocytosis is associated with acute inflammation and dehydration

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

• Expected PaCO_2 for metabolic acidosis: $\text{mmHg} = (\text{HCO}_3 \times 1.5) + 8$; $\text{kPa} = 0.2(\text{HCO}_3) + 1$

Lab data – Case 15

Question:

Your registrar has just reviewed an oncology patient who recently started chemotherapy for a large, abdominal, high grade, non-Hodgkin's lymphoma. The patient has been oliguric for several hours. What is the diagnosis?

Urea 24mmol/L	Glucose 24 mmol/L
Creatinine 239µmol/L	Lipase 89U/L
Na 150 mmol/L	Uric acid 0.49 mmol/L
K 6.4 mmol/L	
Cl 116 mmol/L	pH 7.25

TCO2 17 mmol/l	PaCO2 27 mmHg / 3.60 kPa
	PaO2 124 mmHg 16.53 kPa
Osm 327mOsm/kg	HCO ₃ 12 mmol
	SBE –15 mmol/L
Ca 1.63 mmol/L	Lactate 2.8 mmol/L
Mg 0.99 mmol/L	
PO4 1.45 mmol/L	Hb 10.1 g/dL
Albumin 43 g/L	WCC 18.6 x10 ⁹ /L
	Plt 156 x10 ⁹ /L
Bilirubin 16 µmol/L	
ALT 32 U/L	
AST 34 U/L	
GGT 43 U/L	
ALP 107U/L	
LDH 514 U/L	

Answer:

Diagnosis: Tumour lysis syndrome

Rationale:

High grade lymphomas and leukaemias with high WBC counts are at increased risk of tumour lysis syndrome, as is the first dose of chemotherapy for a large tumour load. Raised K⁺, PO4, LDH and uric acid support the diagnosis. The hyperkalaemia is in excess of that expected for the acidosis – K⁺ rises by 0.5 for every fall in pH of 0.1. The low Ca²⁺ despite a metabolic acidosis has a limited differential, including tumour lysis syndrome and rhabdomyolysis. The

widened AG is due to the release of intracellular acids from lysed cells and contributes to the hyperkalaemia and hyperuricaemia

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

• Expected PaCO_2 for metabolic acidosis: mmHg = $(\text{HCO}_3 \times 1.5) + 8$; kPa = $0.2(\text{HCO}_3) + 1$

Lab data – Case 16

Question:

Your registrar is concerned about a patient in the unit who is proving difficult to wean from ventilatory support. The patient has multiple small bowel fistulae following an open necrosectomy and several revisions for significant necrotising pancreatitis and the surgeons have requested that TPN be continued for 2 – 3 more weeks. The pancreatitis has been settled for some time and all inflammatory markers have returned to normal. Drain outputs are negligible. The patient has a tracheostomy and remains on pressure support ventilation. There are no vasopressors required and the urine output is satisfactory. The patient is receiving an insulin infusion at 12u/hr. The patient is on no antibiotic and has a clear CXR and clear urine microscopy. The observations are as follows: RR 32bpm, SpO₂ 98% (FiO₂ 0.3), HR 110bpm sinus, BP 128/76mmHg, Temp 38.3°C. You are shown the most recent blood results. What is your response?

Urea 11.3mmol/L	Glucose 15 mmol/L
Creatinine 99µmol/L	Lipase 89U/L
Na 147 mmol/L	Uric acid 0.45mmol/L
K 5.5 mmol/L	
Cl 112 mmol/L	pH 7.32
TCO ₂ 29 mmol/l	PaCO ₂ 48 mmHg / 6.39 kPa
	PaO ₂ 154 mmHg / 20.53 kPa
Osm 332.3mOsm/kg	HCO ₃ 28 mmol
	SBE +3 mmol/L
Ca 2.39mmol/L	Lactate 1.1 mmol/L
Mg 1.19 mmol/L	

PO4 1.22 mmol/L	Hb 10.1 g/dL
Albumin 28 g/L	WCC $14.3 \times 10^9/L$
	Plt $259 \times 10^9/L$
Bilirubin 18 $\mu\text{mol/L}$	
ALT 62 U/L	
AST 58U/L	
GGT 121 U/L	
ALP 126 U/L	
Triglycerides 3.01 mmol/L	
Total cholesterol 5.7 mmol/L	

Answer:

Diagnosis: Overfeeding syndrome

Response: Decrease the TPN rate and adjust the contents and proportions to meet the patient's nutritional needs appropriately.

Rationale:

The patient is in the weaning phase and the acute pathology has settled. Therefore complications of therapy must be considered when evaluating new problems. Despite a lack of active pancreatitis markers and no apparent infection source, the patient remains tachypnoeic, tachycardic and hyperthermic. This is due to the increased metabolic state from the excess nutritional supply. The excess nutrition results in hyperglycaemia, (despite being chased by a higher than usual insulin infusion rate in this patient), hyperlipidaemia, mildly deranged LFTs (hepatic steatosis from the hyperlipidaemia) and electrolyte disturbances, along with increased CO₂ production. Patients with overfeeding syndrome may also display delirium, peripheral oedema and excess weight gain.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

- Corrected Ca = Ca + 0.02(40 – albumin)
- Expected HCO₃ for respiratory acidosis: Acute - HCO₃ increases 1mmol/L per 10mmHg rise in p_aCO₂ above 40mmHg (up to 30mmol/L) ; HCO₃ increase 1mmol/L per 1.3kPa rise in p_aCO₂ above 5kPa (up to 30mmol/L)

•Expected HCO₃ for respiratory acidosis: Chronic - HCO₃ increases 4mmol/L per 10mmHg rise in p_aCO₂ above 40mmHg (up to 36mmol/L); HCO₃ increases 4mmol/L per 1.3 rise in p_aCO₂ above 5kPa (up to 36mmol/L)

Lab data – Case 17

Question:

A 56 year old gentleman is transferred from a regional hospital following a difficult intubation for repeated seizures. The intubation was made difficult by tongue swelling that occurred when the patient bit his own tongue during one of his seizures. His initial blood results return as follow:

Na 142mmol/L	Hb 6.7 g/dL
K 3.8 mmol/L	Retics 503 x 10 ⁹ /L
Cl 106 mmol/L	WBC 9.2 x 10 ⁹ /L
HCO ₃ 28mmol/L	Neut 6.5 x 10 ⁹ /L
Urea 10.6 mmol/L	Lymph 2.3 x 10 ⁹ /L
Creatinine 117 µmol/L	MCV 103fl (normal 78-101 fl)
	MCH 35 (normal 25-35 pg/cell)
Uric acid 0.35 mmol/L	MCHC 348 (normal 31 – 36 Hb/cell)
Glucose 11.7 mmol/L	RDW 28.9
	PLT 39 x 10 ⁹ /L
Bili 36 µmol/L	
ALT 13 U/L	Comment: Neutrophils show slight left shift.
AST 29 U/L	Marked polychromasia. Many fragmented red cells.
ALP 75 U/L	
GGT 17 U/L	PT 15.0 s (11.0 – 15.0s)
Alb 31 g/L	INR 1.22

Prot 57 g/L	aPTT 25.8 s (24.0 – 33.0s)
LDH 1,352 U/L	Fibrinogen 3.02 g/L (2.00 – 4.00g/L)
	D-dimer 10.86 µg/ml (<1.00)
Ca 2.03 mmol/L	
PO4 0.69 mmol/L	
Mg 0.89 mmol/L	

a) What diagnosis would you consider?

b) What specific therapy would you consider?

Answer:

Diagnosis: Thrombotic thrombocytopenic purpura

Therapy:

- Plasmapheresis – recommended first line therapy for TTP
- Immunoglobulin
- Methylprednisone

Rationale:

Seizures (neurology) + renal failure + thrombocytopenia + haemolytic anaemia (low Hb + raised reticulocytes + raised LDH + fragmented red cells on the blood film). A history of a febrile illness would complete the TTP pentad. The raised D-dimer is related to the microvascular thrombosis that is part of the pathology

Lab data – Case 18

Question:

A 37 year old lady is in the emergency department with abdominal pain. The emergency registrar is concerned enough to request you to review the blood results and tells you that she is a mildly obese woman, with swelling in the region of both angles of her jaw. Her abdomen is soft with no consistent regional tenderness. She has no known past

medical history and is not on any regular medications. Her heart rate, blood pressure, respiratory rate and oxygen saturation are normal.

Na 120 mmol/L	pH 7.51
K 2.0 mmol/L	PaCO ₂ 49 mmHg / 6.53 kPa
Cl 64 mmol/L	PaO ₂ 103 mmHg / 13.73 kPa
HCO ₃ 48 mmol/L	HCO ₃ 45mmol/L
Urea 4.2 mmol/L	SBE +13
Creatinine 67 µmol/L	SaO ₂ 99%
Glucose 5.5 mmol/L	
Bili 11 µmol/L	
ALT 20 U/L	
AST 34 U/L	
ALP 70 U/L	
GGT 19 U/L	
Alb 38 g/L	
Prot 63 g/L	
Ca 2.24 mmol/L	
PO ₄ 0.98 mmol/L	
Mg 0.85 mmol/L	

a) What diagnosis would you consider?

b) What additional features would you examine for to support your diagnosis?

Answer:

a) Diagnosis: Bulimia nervosa

b) Supportive features: Eroded fingernails, from repeated self-induced vomiting, erosion of dental enamel, especially of the incisors.

Rationale:

Mildly obese female with bilateral parotid swelling, due to repeated self-induced vomiting, and a non-specific abdominal complaint + a metabolic alkalosis which is hypokalaemic and hypochloraemic, which suggests H⁺ ion loss + a hyposmolar hyponatremia due to extra renal sodium loss.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumen})$

• Expected PaCO₂ for metabolic alkalosis: mmHg = ($\text{HCO}_3 \times 0.9$) + 9; kPa = $0.12(\text{HCO}_3) + 1.2$

Lab data – Case 19

Question:

A 31 year old lady is admitted to the ICU from theatres following a dilation and curettage for a foetal death in utero at 18 weeks gestation. She had become febrile and hypotensive over the past 24 hours, precipitating the operation. Her procedure was complicated by heavy blood loss and she received 7 units of packed red blood cells and 4 units of fresh frozen plasma. Her admission haematology is as follows:

Hb 7.6 g/dL	PT 31.9 s (11.0 – 15.0s)
WBC $20.9 \times 10^9/\text{L}$	INR 3.10
Neut $18.7 \times 10^9/\text{L}$	aPTT 85.9 s (24.0 – 33.0s)
Lymph $1.2 \times 10^9/\text{L}$	Fibrinogen 1.22 g/L (2.00 – 4.00g/L)
MCV 99fl (78-101 fl)	Thrombin time 22.1s (15.0 – 19.0s)
MCH 34 (25-35 pg/cell)	D-dimer 8.93 µg/ml (<1.00)

MCHC 338 (31 – 36 Hb/cell)	
RDW 15.3	
PLT 128 x 10 ⁹ /L	

What haematological condition would you suspect?

Answer:

Diagnosis: Disseminated intravascular coagulopathy (DIC)

Rationale:

Raised aPTT, PT, Thrombin time and D-dimer with a low fibrinogen + thrombocytopenia. The likely precipitants include a septic (febrile, hypotensive and leucocytosis) abortion and the massive blood transfusion, which has not followed a 1:1 Packed RBCs to FFP ratio, with no platelets given.

Lab data – Case 20

Question:

A 72 year old gentleman has been intubated in the emergency department for increasing work of breathing and a decline in his level of consciousness during the management of his suspected community acquired pneumonia. The nurse looking after him shows you his first blood gas following his transfer to the ICU. What measures would you take?

FiO2 0.5	Hb 9.1g/dL
pH 7.49	Na 137 mmol/L
PaCO2 26 mmHg	K 3.7mmol/L
PaO2 101 mmHg	iCa 1.13 mmol/L
HCO ₃ 20 mmol/L	iCa (pH 7.40) 1.18mmol/L

SBE -2.8	Glucose 6.3 mmol/L
SaO2 98%	Lactate 1.1 mmol/L

Answer:

Measures to take: Check the ventilator minute ventilation, ventilator frequency and tidal volume. Usually a decrease of the frequency is all that is required. The tidal volume may need to be reduced if inappropriately high. Check that the patient is not in pain and has an appropriate level of sedation to assist tolerance of invasive ventilation. Exclude alternative pathologies, such as meningitis, encephalitis, cerebral oedema or drug toxicities (e.g. salicylate, theophylline).

Rationale:

Diagnosis: Respiratory alkalosis due to overventilation.

Raised pH with a low PaCO₂ and appropriate compensatory fall in the HCO₃ in a mechanically ventilated patient. There is also a raised Aa gradient, though this is unlikely to be driving a tachypnoea given the adequate PaO₂. There is no evidence of a co-existing metabolic acidosis to drive an increased respiratory drive.

- Expected HCO₃ for respiratory alkalosis: Acute - HCO₃ decreases 2mmol/L per 10mmHg fall in paCO₂ below 40mmHg; HCO₃ decreases 2mmol/L per 1.3 fall in paCO₂ below 5kPa
- Expected HCO₃ for respiratory alkalosis: Chronic - HCO₃ decreases 5mmol/L per 10mmHg fall in paCO₂ below 40mmHg; HCO₃ decreases 5mmol/L per 1.3kPa fall in paCO₂ below 5kPa

Lab data – Case 21

Question:

A 48 year old lady is brought to the emergency department confused and febrile, with a heart rate of 140bpm and a blood pressure of 220/97mmHg. She appears mildly cachectic. Her blood tests are presented below.

Na 144 mmol/L	Hb 11.6 g/dL
K 4.4 mmol/L	WBC 15.7 x 10 ⁹ /L
Cl 106 mmol/L	Neut 14.7 x 10 ⁹ /L

HCO ₃ 23 mmol/L	Lymph 0.5 x 10 ⁹ /L
Urea 18.3 mmol/L	MCV 84fl (normal 78-101 fl)
Creatinine 253 µmol/L	MCH 30 (normal 25-35 pg/cell)
	MCHC 34.6 (normal 31 – 36 Hb/cell)
Glucose 11.5 mmol/L	RDW 13.4
CK 562 U/L	PLT 86 x 10 ⁹ /L
Ca 2.11 mmol/L	
PO ₄ 1.38 mmol/L	
Mg 1.10 mmol/L	
Free T ₄ 47.8 pmol/L (10.5 – 21.2pmol/L)	
TSH 0.050 mIU/L (0.35 – 0.36mIU/L)	
Free T ₃ 6.6 pmol/L (2.5 – 7.3pmol/L)	

What specific therapy would you suggest?

Answer:

Therapy, in order of administration:

- Decrease the systemic sensitivity of catecholamine receptors and the peripheral conversion of T₄ to T₃ using non-selective β-blocker: Propranolol 0.5 – 1mg IV q5min until HR less than 100bpm to maximum 10mg, then enteral propranolol 60 – 120mg q4hr until the crisis abates. Cardioselective β-blockers can be used, but are less effective. Guanethedine or reserpine are used in patients with reactive airways disease or other contraindications to β-blockers.
- Reduce thyroid hormone synthesis: Enteral propylthiouracil 1000mg loading dose, then 200 – 400 mg q4hr. Carbimazole has also been used.
- Reduce the release of preformed thyroid hormone: Lugol's iodine 8 - 10 drops q6hr enterally. Alternatively, iodinated contrast agent can be used if Lugol's iodine is not available.
- Steroids: Hydrocortisone 300 mg loading followed by 100 mg tds, as there is often a relative hypoadrenalism. It also alters the peripheral conversion of existing thyroid hormones. .

- Treat the precipitant – usually sepsis.
- Supportive therapy – fluid balance, nutritional support, avoid salicylates and frusemide which can release bound thyroid hormone, active cooling of hyperpyrexia, thiamine and sedation if agitated.

Rationale:

Diagnosis: Hyperthyroid crisis

High T4 with suppressed TSH is consistent with primary hyperthyroidism (Grave's disease, toxic multinodular goitre, acute Reidel's thyroiditis, amiodarone-induced thyroiditis). Also consistent with a thyrotoxic crisis is her clinical presentation with fever, confusion and increased heart rate and BP. Associated laboratory abnormalities include hyperglycaemia (including non-diabetics), raised WBC, raised Ca^{2+} and low K^+ and Mg^{2+}

Lab data – Case 22

Question:

A 19 year old lady has been brought to the emergency department by her friends, in a state of inebriation. She is tearful and incoherent, requiring a small dose of midazolam to calm her. Her friends state that she recently broke up with her boyfriend. What therapy would you consider based on her blood results?

Na 143 mmol/L	Hb 12.4g/dL
K 4.7 mmol/L	WBC $13.6 \times 10^9/\text{L}$
Cl 99 mmol/L	Neut $11.7 \times 10^9/\text{L}$
HCO_3^- 19 mmol/L	Lymph $1.2 \times 10^9/\text{L}$
Urea 5.9 mmol/L	MCV 90fl (normal 78-101 fl)
Creatinine 182 $\mu\text{mol/L}$	MCH 31 (normal 25-35 pg/cell)
	MCHC 33.8 (normal 31 – 36 Hb/cell)
Glucose 5.9 mmol/L	RDW 10.9
	PLT $201 \times 10^9/\text{L}$
Bili 113 $\mu\text{mol/L}$	
ALT 2029 U/L	PT 34.3 s (11.0 – 15.0s)
AST 3006 U/L	INR 3.24

ALP 39 U/L	aPTT 41.7 s (24.0 – 33.0s)
GGT 38 U/L	Fibrinogen 2.32 g/L (2.00 – 4.00g/L)
Alb 33 g/L	Thrombin time 17.6s (15.0 – 19.0s)
Prot 52 g/L	D-dimer >20.0 µg/ml (<1.00)
Ca 1.88 mmol/L	FiO2 0.3
PO4 1.84 mmol/L	pH 7.23
Mg 1.12 mmol/L	PaCO2 46 mmHg / 6.13 kPa
	PaO2 89 mmHg / 11.87 kPa
	HCO ₃ 19 mmol/L
	SBE -7.6
	SaO2 97%

Answer:

Therapy:

- Consider ventilatory support for the respiratory acidosis, as her impaired liver may not metabolise the "small dose of midazolam" effectively.
- Start N-acetylcysteine infusion.
- Vitamin K is often not given in this situation, unless there is significant bleeding, as it is used to monitor the progress of the liver failure.
- FFP is not required unless there is bleeding.
- By the King's College Hospital criteria for liver transplantation for paracetamol-induced acute liver failure, she should be referred for early consideration for liver transplantation.
- Once the acute organic illness has settled, she will require a psychiatry assessment (Don't forget about this important component of her overall management!)

Rationale:

Diagnosis: Acute liver failure due a combination of alcohol and paracetamol overdose

The mode of presentation is highly suggestive of a reactive suicide attempt and a combination of paracetamol and alcohol is the most common in young women. The LFTs suggest an acute hepatitis and a transaminitis in the thousands suggests either an ischaemic or, in this case, a toxic aetiology. The coagulopathy and raised bilirubin are consistent with liver failure and a raised INR is one of the earliest indicators of paracetamol induced liver failure. Her ABG demonstrates a mixed respiratory and raised AG metabolic acidosis, which is likely to be attributable to a lactic acidosis, secondary to her liver failure.

- $AG = (Na) - (Cl + HCO_3 \text{ or } TCO_2)$. Normal 6-15mmol/L
- Expected $PaCO_2$ for metabolic acidosis: $mmHg = (HCO_3 \times 1.5) + 8$; $kPa = 0.2(HCO_3) + 1$

King's College Hospital criteria for liver transplantation for paracetamol-induced acute liver failure.

- $pH < 7.3$, or,
- $INR > 6.5$ and Serum creatinine $> 300\mu\text{mol/L}$ and West-Haven III-IV hepatic encephalopathy

Lab data – Case 23

Question:

A short synacthen test has been performed on one of your patients who is being treated for severe respiratory sepsis. How would you interpret the result?

Na 134 mmol/L	<u>Synacthen 0.25mg</u>
K 5.7 mmol/L	Cortisol T-0 411 nmol/L
Cl 105 mmol/L	Cortisol T-30 581 nmol/L
HCO_3 23 mmol/L	
Urea 5.9 mmol/L	
Creatinine 182 $\mu\text{mol/L}$	

Answer:

Interpretation: While the renal biochemistry and failure of cortisol to rise above the 600nmol/L threshold after synacthen suggest adrenal insufficiency in the setting of severe sepsis, the implications of this on management are much debated.

The concept of relative adrenal insufficiency is not universally accepted, with concerns about validation of measurement thresholds in critical illness and the interpretation of results obtained when critical illness has altered plasma proteins and total and free cortisol fractions. Therefore, the use of stress dose steroids remains controversial. My practice is to

Rationale:

Diagnosis: The renal biochemistry and result of the short synacthen test suggests adrenal insufficiency, which is a much debated pathology associated with critical illness and severe sepsis in particular.

Hyponatraemia + hypokalaemia + normal AG metabolic acidosis. A baseline cortisol (T-0, time zero) between 100 – 550nmol/L is neither specific for adrenal insufficiency nor adequacy. However, while a rise in cortisol level to less than 600nmol/L, or by less than 250nmol/L, by 30 minutes (T-30) after synacthen administration is consistent with adrenal insufficiency in an outpatient population, its implications for a critically ill patient is still hotly debated.

Lab data – Case 24

Question:

A 20 year old male is involved in a high speed car crash arrives in ICU after having internal fixation of a femoral fracture and application of external fixation to a complex pelvic fracture. Large volumes of fluids and blood products were infused in the Emergency Department then in the operating theatre. The arterial blood gas on arrival to ICU and the electrolytes sampled around this time are available. What is the likely cause of the acidosis and why? Analyse the results using concepts from the Stewart theory.

<u>Blood gases:</u>	<u>Electrolytes:</u>
FiO2 0.5	
pH 7.28	Na 146 mmol/L
paCO2 36 mmHg / 4.79 kPa	K 3.3 mmol/L
paO2 125 mmHg / 16.67 kPa	Cl 115 mmol/L
HCO ₃ 21 mmol/L	HCO3 21 mmol/L
Lactate 1.4 mmol/L	Urea 7.9 mmol/L
	Creat 90 µmol/L

	Albumin 33 mmol/L
	Phosphate 1.8 mmol/L

Answer:

In the setting of a high chloride and the clinical context of needing large volumes of fluid and blood product resuscitation the likely cause is a hyperchloraemic acidosis.

In this case:

- $SID = 21 + (0.28 \times 33 + 2.14 \times 1.8) = 21 + 9.24 + 3.85 = 34.1$
- This is less than 42, a low SID
- $SIG = [(146 + 3.3) - (21 + 115)] - (9.24 + 3.85) = (149.3 - 136) - 13.09 = 0.2$
- This is around 0, a normal SIG

Rationale:

The equations that are of practical relevance presented as follows:

- $SID = [HCO_3^-] + A^-$ (where normal is approximately 42)
- $SIG = \text{Anion gap} - A^-$ (where normal is approximately 0)
- where $A^- = 0.28 \times \text{Albumin (g/L)} + 2.14 \times \text{Phosphate (mmol/L)}$

• $\text{Anion gap} = [Na^+ + K^+] - [HCO_3^- + Cl^-]$

Lab data – Case 25

Question:

A 38 year old lady was admitted to the ICU 7 days ago for a massive PE, which was thrombolysed successfully and remains on IV anticoagulation. She is being weaned from the ventilator, having been treated with appropriate antibiotics for an aspiration pneumonia that occurred during the original intubation. The nurse raises a concern about apparent swelling of her right upper limb and shows you her most recent blood results. What specific laboratory tests would you request?

Na 141 mmol/L	Hb 12.9g/dL
K 4.3 mmol/L	WBC $8.6 \times 10^9/L$
Cl 97 mmol/L	MCV 82fl (normal 78-101 fl)

HCO ₃ 26 mmol/L	MCH 29pg (normal 25-35 pg/cell)
Urea 6.9 mmol/L	MCHC 33.6 (31 – 36 Hb/cell)
Creatinine 89 µmol/L	PLT 56 x 10 ⁹ /L
Glucose 6.3 mmol/L	PT 14.3 s (11.0 – 15.0s)
	INR 0.9
Bili 13 µmol/L	aPTT 44.9 s (24.0 – 33.0s)
ALT 29 U/L	Fibrinogen 3.02 g/L (2.00 – 4.00g/L)
AST 30 U/L	Thrombin time 14.6s (15.0 – 19.0s)
ALP 22 U/L	D-dimer <1.0 µg/ml (<1.00)
GGT 31 U/L	
Alb 37 g/L	
Prot 58 g/L	
Ca 2.38 mmol/L	
PO4 1.02 mmol/L	
Mg 0.97 mmol/L	

Answer:

Laboratory tests:

- HIT screen for heparin-PF4 complex antibodies. Confirmation by a positive activation test, using donor platelet serotonin release, is generally not required as it is more difficult and expensive due to the need for specific donor platelets. A positive PF4 assay with resolution of the platelet count after cessation of the heparin is considered confirmatory, although false negative PF4 assays can occur.
- Lupus anticoagulant
- SLE screen: ANA, anti-dsDNA, anti smooth muscle antibody, VDRL, anticardiolipin antibody, serum complement. Lupus anticoagulant is often positive in SLE.

Rationale:

Diagnosis: HIT type 2

The combination of a raised aPTT with the occurrence of a possible venous thrombosis (the swollen right upper limb) has a limited differential – HIT, lupus anticoagulant or an intravascular device, which has probably become infected, in someone on heparin. The presence, degree and timing of the thrombocytopenia favours HIT, although SLE is still a possibility

Lab data – Case 26

Question:

A 61 year old patient has been receiving continuous renal replacement therapy in your ICU for contrast induced acute renal failure. The nurse shows you the latest set of bloods for review. What is your response?

Na 137 mmol/L	Hb 11.3g/dL
K 3.8 mmol/L	WBC $7.7 \times 10^9/L$
Cl 95 mmol/L	MCV 80fl (normal 78-101 fl)
HCO ₃ 28 mmol/L	MCH 30pg (normal 25-35 pg/cell)
Urea 15.0 mmol/L	MCHC 33.9 (31 – 36 Hb/cell)
Creatinine 219 $\mu\text{mol/L}$	PLT $156 \times 10^9/L$
Glucose 8.3 mmol/L	PT 12.6 s (11.0 – 15.0s)
Bili 10 $\mu\text{mol/L}$	INR 0.8
ALT 23 U/L	aPTT 31.0 s (24.0 – 33.0s)
AST 26 U/L	
ALP 34 U/L	
GGT 45 U/L	

Alb 33 g/L	
Prot 51 g/L	
Ca 1.58 mmol/L	
iCa 0.81mmol/L	
PO4 0.82 mmol/L	
Mg 0.57 mmol/L	

Answer:

Response: Check the pre-filter citrate infusion rate. Increase the post filter calcium infusion rate.

Rationale:

Diagnosis: Biochemical effect of citrate anticoagulated dialysis.

In general, CRRT dialysis circuits require some form of anticoagulation, in order to preserve filter life by minimising filter thrombosis. Typically this is done with heparin, which usually results in an elevation of the aPTT, even if post filter protamine is used (regional heparinisation). Alternatives include fondaparinaux, danaparoid, a hirudin analogue (eg bivalirudin, lepirudin) and citrate. There has been a resurgent interest in citrate dialysis recently and, of all of the above anticoagulant alternatives, only citrate excess results in a hypoglycemic hypomagnesaemia. The mildly raised HCO_3^- is likely to be due to the hepatic metabolism of systemic citrate

Lab data – Case 27

Question:

This 70 year old female presented with dizziness and had a history of recent syncopal episodes. On examination she had a loud ejection systolic murmur noted which radiated to her carotid arteries. An echocardiogram demonstrated severe aortic stenosis with features suggesting a calcification bicuspid valve. She was admitted for surgery and the following pre-operative blood results were noted:

WBC $5.0 \times 10^9/\text{L}$ (3.5-10)	HCT 0.16 (normal 0.35-0.40)
RBC $1.94 \times 10^9/\text{L}$ (3.8-5.1)	MCV 70 fl (normal 78-101 fl)

HGB 48 g/L (120-150)	MCH 22 pg/cell (normal 25-35 pg/cell)
----------------------	---------------------------------------

a) Interpret the results. What is the most common cause of this picture? What test will you order to confirm your suspicion?

b) The patients Iron studies were performed.

Iron 3 $\mu\text{mol/L}$ (low)

Total Iron Binding Capacity 92 $\mu\text{mol/L}$ (high)

Ferritin 6 $\mu\text{g/L}$ (low)

Do these results confirm your suspected diagnosis? What is a single unifying diagnosis that would tie together this picture and severe aortic stenosis?

Answer:

a) There is a marked microcircuit, hypochromic anaemia. The most likely cause is iron deficiency anaemia. Iron studies will be helpful.

b) Yes. The results are consistent with Iron deficiency anaemia. There are a number of potential causes of this that need investigating, but angiodysplasia is a known association with severe aortic stenosis where it is termed Heyde's Syndrome. It is thought that von Willebrand factor is proteolysed due to high shear stress from turbulent flow across the diseases aortic valve, increasing the risk of bleeding from intestinal telangiectasias that are increasingly common with advancing age.

Lab data – Case 27

Question:

This 70 year old female presented with dizziness and had a history of recent syncopal episodes. On examination she had a loud ejection systolic murmur noted which radiated to her carotid arteries. An echocardiogram demonstrated severe aortic stenosis with features suggesting a calcification bicuspid valve. She was admitted for surgery and the following pre-operative blood results were noted:

WBC $5.0 \times 10^9/\text{L}$ (3.5-10)	HCT 0.16 (normal 0.35-0.40)
RBC $1.94 \times 10^9/\text{L}$ (3.8-5.1)	MCV 70 fl (normal 78-101 fl)
HGB 48 g/L (120-150)	MCH 22 pg/cell (normal 25-35 pg/cell)

a) Interpret the results. What is the most common cause of this picture? What test will you order to confirm your suspicion?

b) The patients Iron studies were performed.

Iron 3 $\mu\text{mol/L}$ (low)

Total Iron Binding Capacity 92 $\mu\text{mol/L}$ (high)

Ferritin 6 $\mu\text{g/L}$ (low)

Do these results confirm your suspected diagnosis? What is a single unifying diagnosis that would tie together this picture and severe aortic stenosis?

Answer:

a) There is a marked microcircuit, hypochromic anaemia. The most likely cause is iron deficiency anaemia. Iron studies will be helpful.

b) Yes. The results are consistent with Iron deficiency anaemia. There are a number of potential causes of this that need investigating, but angiodysplasia is a known association with severe aortic stenosis where it is termed Heyde's Syndrome. It is thought that von Willebrand factor is proteolysed due to high shear stress from turbulent flow across the diseases aortic valve, increasing the risk of bleeding from intestinal telangiectasias that are increasingly common with advancing age

Lab data – Case 28

Question:

A 65-year-old man underwent a Whipple's procedure for resection of a pancreatic adenocarcinoma. An anastomotic leak and pancreatic fistula complicated this. Total parenteral nutrition was provided. After a month of TPN trace elements were ordered and the results shown:

Plasma/serum chromium 5 nmol/L (1-26 nmol/L)

Plasma/serum selenium 0.9 $\mu\text{mol/L}$ (0.9-1.4 $\mu\text{mol/L}$)

Plasma/serum zinc 2.6 $\mu\text{mol/L}$ (10-19 $\mu\text{mol/L}$)

Plasma/serum copper 14.8 $\mu\text{mol/L}$ (12-22 $\mu\text{mol/L}$)

Blood manganese 90 nmol/L (60-350 nmol/L)

Blood selenium 1.1 $\mu\text{mol/L}$ (1.2-2.1 $\mu\text{mol/L}$)

Comment on the findings.

Answer:

The results suggest a deficiency of zinc and to a lesser degree selenium.

Both trace elements are known to commonly fall in critically ill patients, including surgical patients requiring TPN. Both are important antioxidants involved in host defense against free radicals. Zinc is also involved in wound healing and glycaemic control. The risks, benefits and most appropriate regimen for replacing trace elements in the critically ill patient remains unclear although this is an area of current active research

Lab data – Case 29

Question:

A 22 year old lady has been in the ICU for management of her septic shock secondary to ascending cholangitis. Overnight, as her therapy was being weaned she received an accidental bolus of noradrenalin, resulting in a brief period of significant hypertension. Subsequently, she has been complaining of a severe headache, requiring increasing boluses of opiate analgesia. A head CT was performed the following day and has been reported as normal. A lumbar puncture is performed and you are shown the results. What is your interpretation? What investigation would you request next?

<u>CSF</u>	<u>Blood</u>
Protein 0.59g/L (0.15 – 0.45g/L)	Glucose 7.2mmol/L
Glucose 6.9mmol/L (2.5 – 5.6mmol/L)	Hb 12.9g/dL
Appearance: clear, xanthochromic supernatant	WBC $13.5 \times 10^9/L$
RBC $5340 \times 10^9/ml$	PLT $435 \times 10^9/L$
Polymorphs $8 \times 10^9/ml$	
Mono $6 \times 10^9/ml$	

Answer:

Diagnosis: Subarachnoid haemorrhage, secondary to catecholamine surge

Investigation: A CT angiogram, to look for cerebrovascular aneurysms.

Rationale:

A severe headache after a period of significant hypertension raises the possibility of an intracranial haemorrhage (SAH, intracerebral) or a carotid or vertebral artery dissection. A head CT should reliably show an intracerebral haemorrhage, but if there is a delay in performing it, a subarachnoid haemorrhage may be missed due to reduced sensitivity. However, as the sensitivity of a head CT for an SAH declines over the initial 24 hours, the sensitivity of an LP improves. The red cell to white cell ratio ($>300 - 500:1$) of the sample above does not support an infective aetiology

Lab data – Case 30

Question:

A 32 year old gentleman is admitted to your ICU for management of his septic shock following a right sided percutaneous nephrostomy tube insertion for obstructive ureterolithiasis which has resulted in right sided pyelonephritis. He has been commenced on empiric ceftriaxone and is on $0.7\mu\text{cg/kg/min}$ of noradrenalin. The following day a microbiology report is phoned through to the department and handed to you. What would you do next?

Urine microscopy

RBCs $>100 \times 10^9/\text{ml}$

WBC $> 100 \times 10^9/\text{ml}$

Epithelial $< 10 \times 10^9/\text{ml}$

Organisms seen

Culture: Pure growth E.coli

This organism has tested positive for ESBL

Answer:

Intervention: Change the cephalosporin antibiotic to a carbapenem; e.g. meropenem, imipenem.

Rationale:

ESBL organisms, typically gram negative enterobacteriaceae such as E.coli and klebsiella, have a plasmid transmission mediated β -lactamase, rendering them resistant to β -lactam antibiotics. The use of a β -lactamase inhibitor such as clavulanate or tazobactam has not resulted in reliable activity against these organisms. They are often also multiply resistant to quinolones and aminoglycosides. Carbapenems have had reliable activity against ESBL organisms despite persistent use.

Lab data – Case 31

Question:

A 79 year old lady is in your ICU being treated for severe necrotising pancreatitis. A blood culture that was taken following a new fever is returned. What therapeutic strategy would you choose?

Blood culture

Site: Blood

Culture: 10^3 cfu Enterococcus faecium (Van-A) isolated

Site: CVC

Culture: 10^4 cfu Enterococcus faecium (Van-A) isolated

Answer:

Strategy:

- Replace all vascular catheters, ideally with a 72 hour gap if feasible, and consider using an antibiotic impregnated catheter
- Send repeat blood cultures from peripheral sites, the old catheters prior to removal and the new catheters once sited. Also send the old catheter tips for culture.

- Start synergid or tygecycline, given the presence of a septicaemia.
- Move the patient to an isolation room and employ full barrier nursing procedures, especially hand washing.

Rationale:

Diagnosis: Vancomycin resistant enterococcus faecium catheter related blood stream infection.

Definitions for a catheter related blood stream infection (CRBSI) vary and include growth of >15 colonies (semiquantitative analysis), or 10^3 + cfu (quantitative analysis), from a distal or proximal catheter segment, or isolation of 5 - 10 times the colony count from a catheter aspirated blood sample as from a peripheral sample, or positive growth from the catheter sample occurs 2 hrs before peripheral sample, in the presence of features of infection. Defervescence of the fevers after removal of a suspect vascular catheter is also accepted as evidence of a CRBSI.

There are 3 levels of vancomycin resistance amongst enterococcal species

- Van-A: High level resistance. Cannot use Vancomycin or Teicoplanin. Use tygecycline (E. faecium & faecalis) or synergid (E. faecium only)
- Van-B: Vanc resistance induceable, but can use Teicoplanin, though long term use may result in resistance
- Van-C 1 - 3: Low level resistance

-

• Lab data – Case 32

• Question:

- A 74 year old gentleman is admitted to the ICU for management of septic shock due to a community acquired pneumonia. He is difficult to ventilate and a CXR shows a large left sided pleural effusion. This is therapeutically tapped and the cloudy fluid sent for analysis. What is your interpretation of the results?

<u>Pleural fluid</u>	<u>Blood</u>
Glucose 0.1 mmol/L	Urea 12.6 mmol/L
Protein 54 g/L	Creatinine 173 μ mol/L
LDH 4522 U/L	Na 135 mmol/L
pH 7.12	K 5.0 mmol/L
	Cl 102 mmol/L
WBC > 10×10^9 /ml	HCO3 24 mmol/L
RBC > 10×10^9 /ml	

Gram stain: Polymorphs + +

Bili 10 μ mol/L

ALT 23 U/L

AST 26 U/L

ALP 34 U/L

GGT 45 U/L

LDH 202 U/L

Protein 64 g/L

Albumin 20 g/L

Glucose 9.2 mmol/L

-
-

- **Answer:**

- Diagnosis: Empyema

- **Rationale:**

- The patient is being treated for a pneumonia, which acts as the source for the empyema. The tapped fluid is cloudy and, by Light's criteria (Effusion to serum protein ratio > 0.5 , effusion to serum LDH > 0.6 , effusion LDH $> 2/3$ upper limit of normal serum LDH), suggests an exudative effusion. Other indicators of an exudate include effusion protein > 30 g/L and a serum to effusion albumin gradient < 1.2 g/L. The low effusion pH and extremely low effusion glucose are very suggestive of an empyema as a cause of the effusion.

Lab data – Case 33

Question:

A 59 year old patient has been in ICU for 6 days, subsequent to an out of hospital cardiac arrest. He has shown a slow neurological recovery and is due to have a tracheostomy placed to facilitate weaning from his ventilator. He began to have febrile episodes on day 4 of his admission and his CXR shows a new right middle lobe infiltrate. A non-directed bronchoalveolar lavage was sent for analysis and the results have returned. What strategies would you employ to minimise the risk of this complication?

Sputum

Appearance: Mucopurulent

RBCs $>10 \times 10^9/\text{ml}$

WBC $> 100 \times 10^9/\text{ml}$

Epithelial $< 10 \times 10^9/\text{ml}$

Organisms seen. GPC in clusters.

Culture: Staph aureus (Mec-A gene detected)

Answer:

Strategies:

1. For prevention of VAP

- Avoid unnecessary intubation
- Minimise duration of invasive ventilation
- Head up 30 - 45 degrees
- Feed enterally rather than parenterally. Benefit possibly offset by presence of NG tube, compromising lower oesophageal sphincter function
- Maintain normoglycaemia, especially DM
- The role of supraglottic suction catheter is not universally accepted as yet
- The roles of selective digestive decontamination or selective oral decontamination remain controversial

2. For prevention of transmission of an MRO

- Adherence to barrier nursing principles
- Hand washing before and after patient contact
- The use of alcohol based hand rubs
- Adherence to the principles of appropriate use of antibiotics in order to minimise the evolution of colonisation to infection
- Minimising the use of invasive devices
- Eliminating infection reservoirs

Rationale:

Diagnosis: Late onset MRSA ventilator-associated pneumonia (VAP)

- A ventilator-associated pneumonia is defined as pneumonia occurring more than 48 hours of initiating mechanical ventilation or within 48 hours of extubation (American Thoracic Society Guidelines definition). It is further classified as early (day 1 – 4 post intubation, community acquired organisms) or late (day 5 or more post intubation, nosocomial organisms), which alters the spectrum of organisms likely to be involved.
- The Mec-A gene confers methicillin resistance on to staphylococcus aureus (MRSA).

• Lab data – Case 34

• Question:

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- A 63 year old patient who has been ventilated for 8 days for ARDS of unknown aetiology has had a resurgence of febrile episodes. His sputum samples persistently return a growth of a gram negative rod despite therapeutic gentamicin levels and adequate doses of Piperacillin-Tazobactam. What implications does this have for the ICU?

• Answer:

- The concern is the emergence of a multidrug resistant (MDR) Gram negative organism (e.g. Pseudomonas, ESBL, ESCAPM agent, Stenotrophomonas maltophilia). Some acquire resistance, others, like stenotrophomonas, are inherently multiply-resistant environmental gram negative organisms. Its isolation suggests that this patient has been on prolonged broad spectrum antibiotics. The patient must be isolated and strict barrier nursing and contact precautions must be taken in order to prevent horizontal transmission to other patients. Transmission to immunosuppressed, critically ill patients is devastating, especially inherently multiply resistant organisms, such as stenotrophomonas which only have a limited range of effective antibiotics available for their treatment.
- The second concern is that the organism cannot be reached by the antibiotics if, for example, an abscess or a loculated empyema has formed. This requires a focussed assessment in order to determine the most appropriate treatment

Lab data – Case 35

Question:

A 45 year old renal transplant patient is admitted to hospital with fevers, a dry cough and a single episode of haemoptysis. An ICU consult is sought when, on the ward, his oxygen saturation deteriorates and his work of breathing increase, despite increasing his FiO₂ to 15L/min via non-rebreather mask. On examination, he is in moderate respiratory distress and hypoxic with a tachycardia and normal blood pressure. His CXR shows bilateral patchy infiltrates. He is intubated and a bronchoscopic BAL is performed. List the possible responsible organisms and the antimicrobial agent you would commence.

Answer:

Bacterial	Antimicrobial agent
• Typical	• Benzylpenicillin, ampicillin or ceftriaxone + macrolide (e.g. azithromycin)

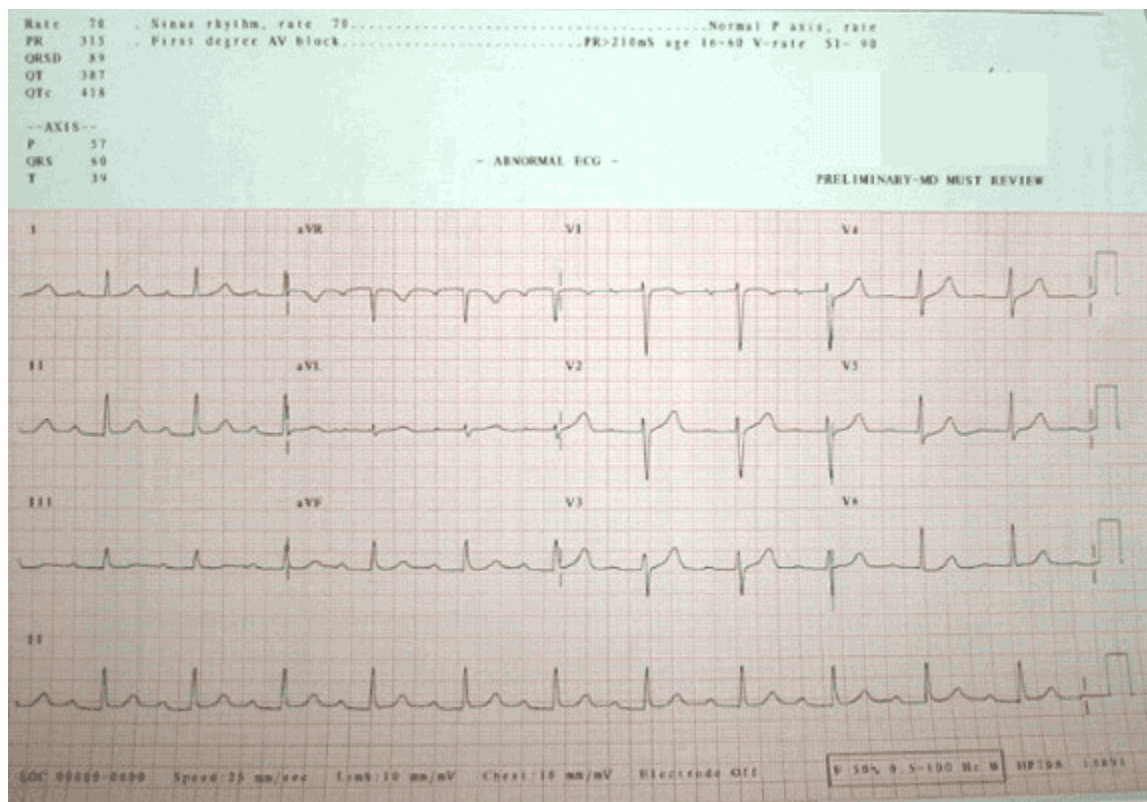
<p>community acquired organisms (strep, haemophilus, moraxella)</p> <ul style="list-style-type: none"> • Atypical non-zoonotic community acquired organisms (legionella, mycoplasma, chlamydia pneumonia) • Atypical zoonotic community acquired organisms (chlamydia psittaci, Q fever, Francisella tularensis) • High risk community acquired pneumonia (staphylococcus, enteric gram negative organisms) • Nosocomial organisms • TB <p>Viral</p> <ul style="list-style-type: none"> • CMV • HSV • Chicken pox <p>Fungal</p> <ul style="list-style-type: none"> • Pneumocystis jirovecii (formerly PCP) • Invasive aspergillosis • Invasive candidiasis 	<ul style="list-style-type: none"> • Ampicillin + macrolide (e.g. azithromycin) • Doxycycline, moxifloxacin or a macrolide (e.g. azithromycin) • Flucloxacillin • Ceftriaxone or moxifloxacin • Timentin + gentamicin ± vancomycin • Rifampicin + isoniazid (pyridoxine) + pyrazinimide + ethambutol • Ganciclovir • Aciclovir or Valaciclovir • Aciclovir or Valaciclovir • Co-trimoxazole (Bactrim) • Voriconazole • Generally fluconazole sensitive, unless <i>C. glabrata</i> or <i>C. krusei</i>, in which cases use amphotericin B or voriconazole
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Data interpretation

ECG – Case 1

Question:

List 4 conditions associated with this abnormality



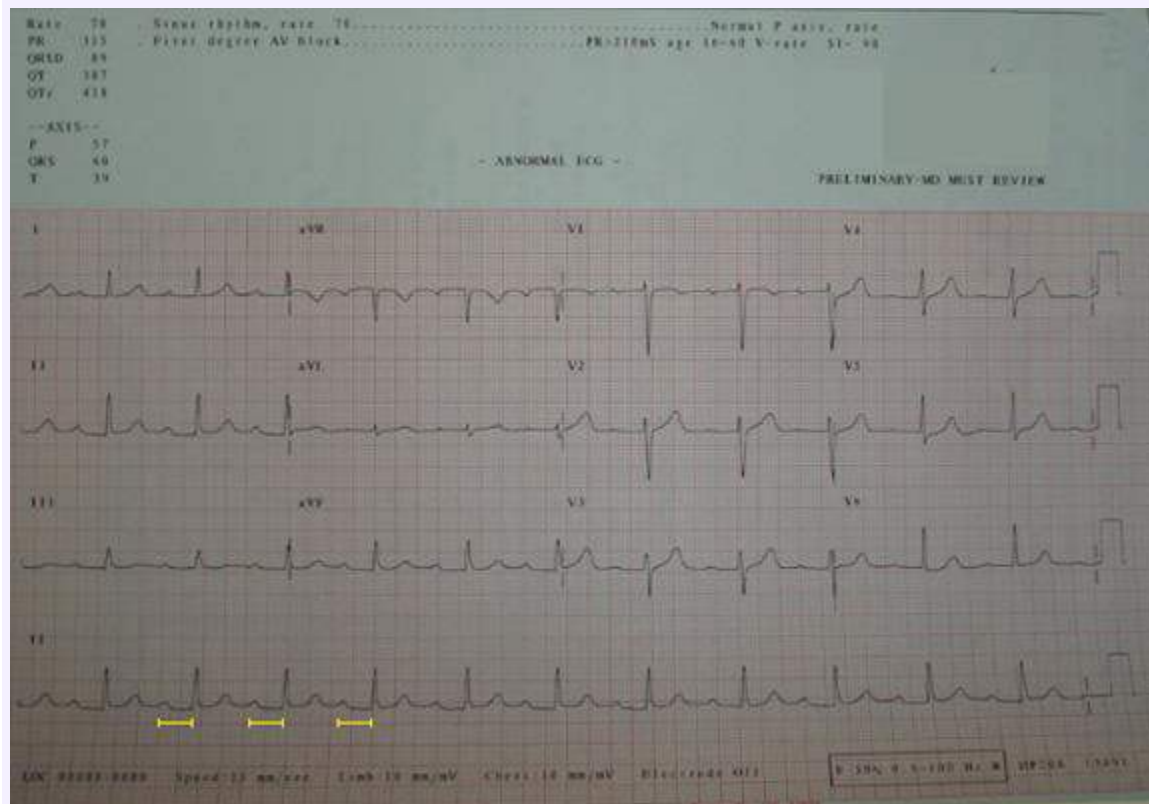
Answer:

Diagnosis = 1st degree heart block

Associated conditions

9. Normal variant
10. Inferior AMI
11. Myocarditis
12. Digoxin toxicity

Also, any cause of increased vagal tone



Rate = 76bpm.

Normal axis.

Sinus rhythm with prolonged PR segment (8 small boxes, or 0.32s – yellow bars)

Normal QRS and QT duration

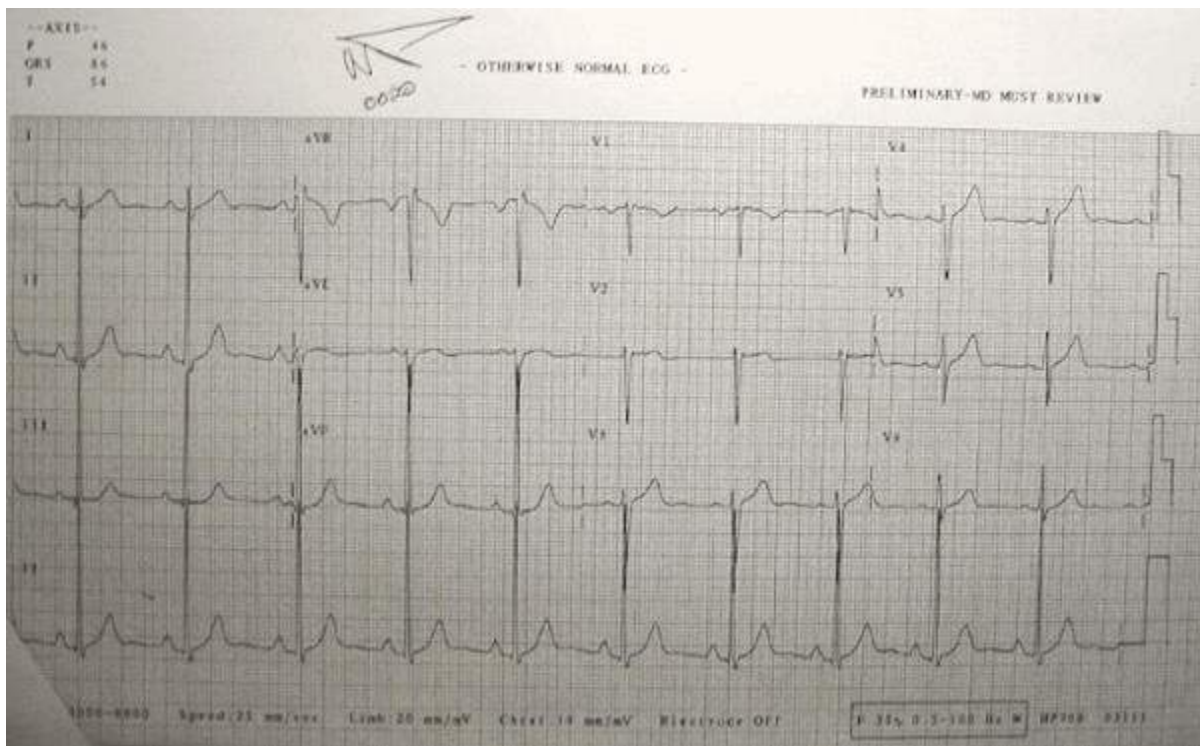
Normal P, QRS and T wave morphology

03:44

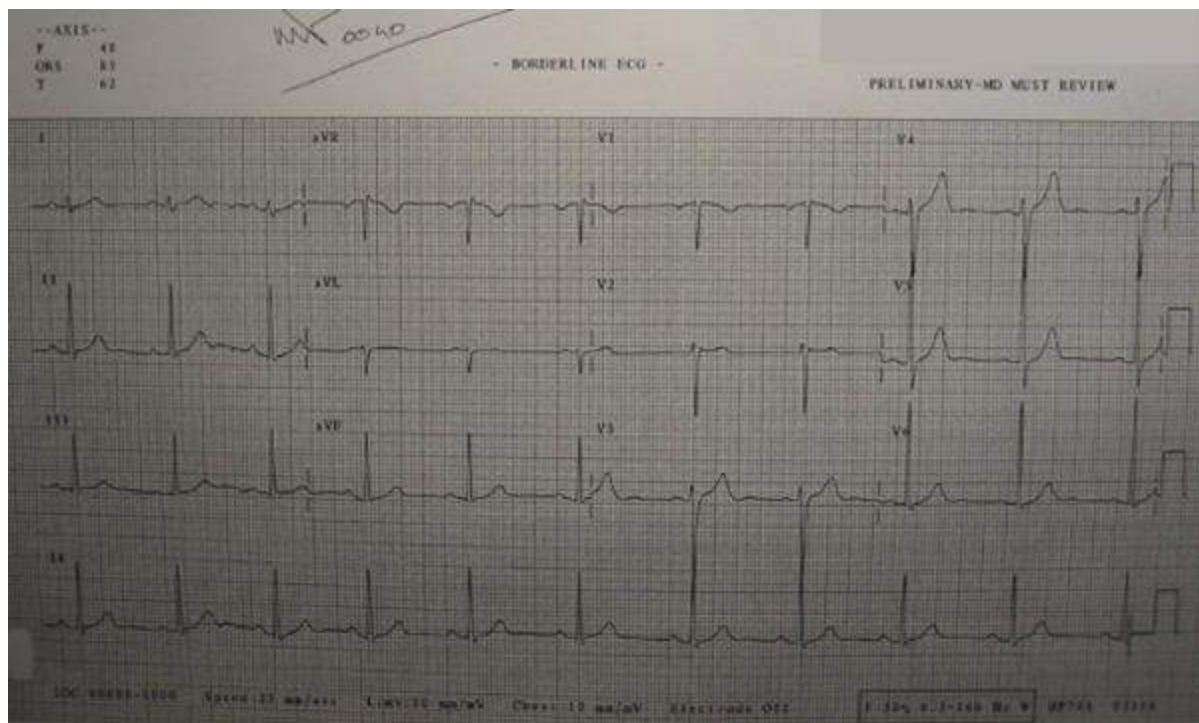
ECG – Case 2

Question:

- a) Describe the features of this ECG



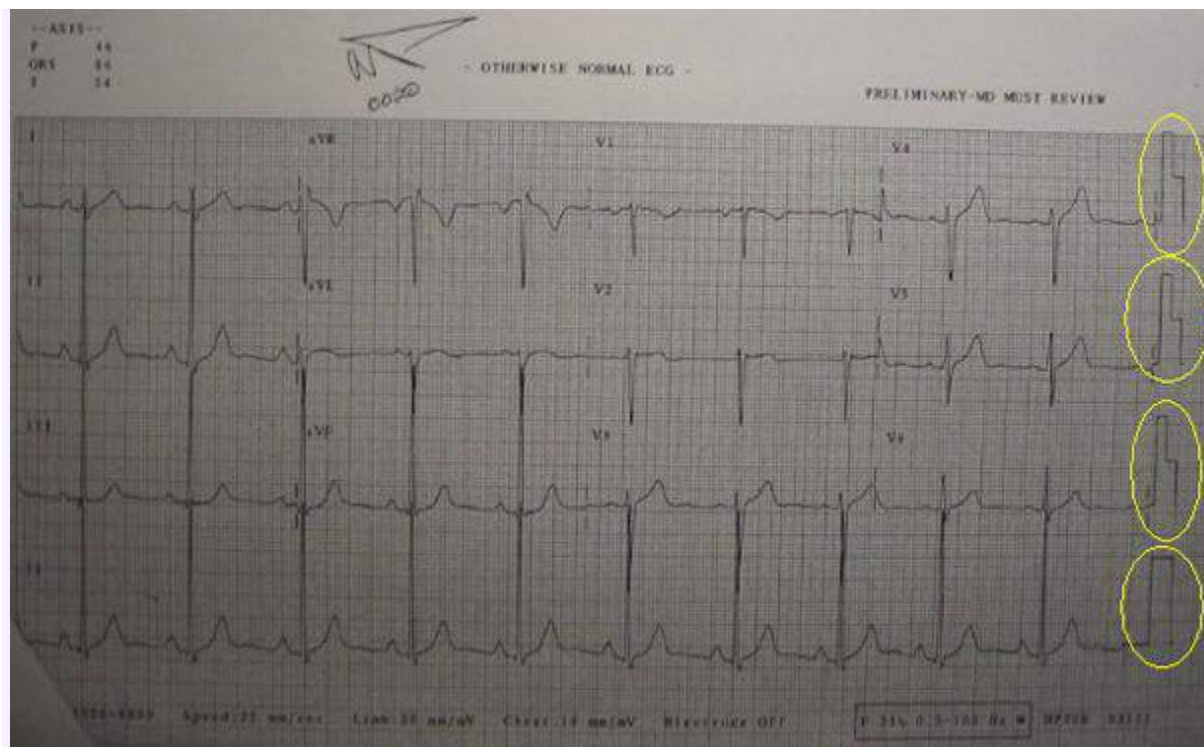
- b) With the voltage calibration corrected, describe the ECG as shown below



Answer:

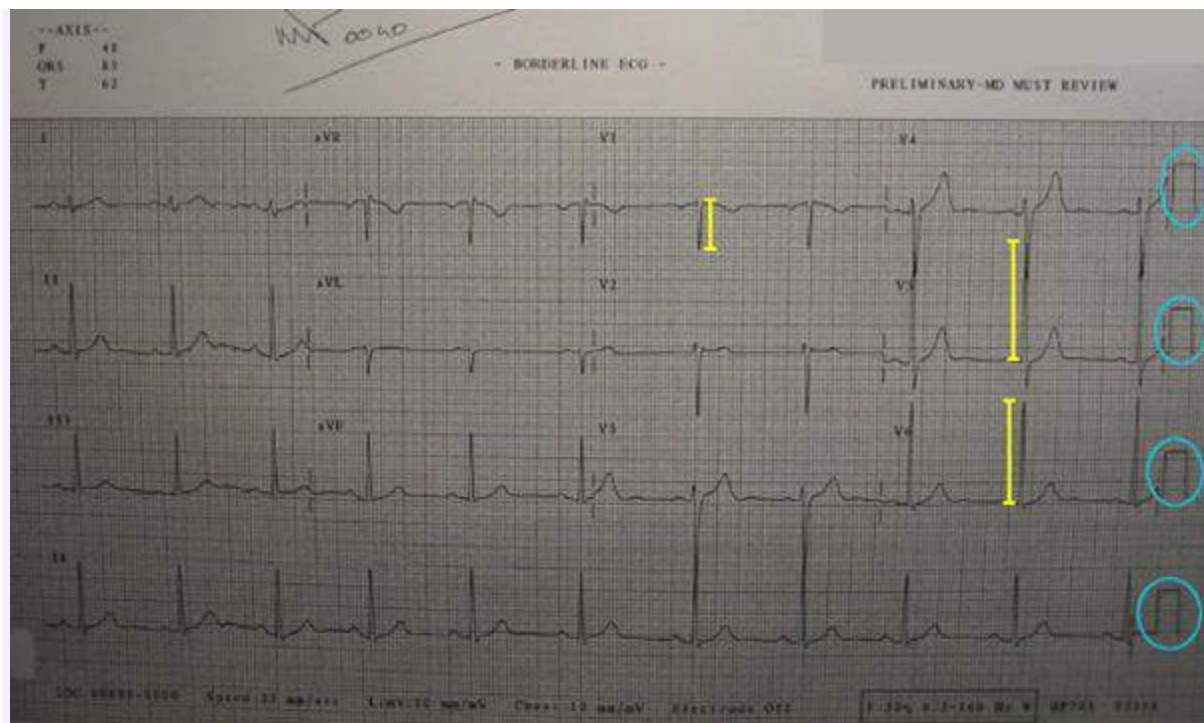
Description: There is a voltage calibration error (yellow circles), resulting in distortion of the height of the P and T waves and the QRS complexes. The paper speed is correct (25mm/sec), so the rhythm is sinus at about 60bpm.

Diagnosis = Voltage calibration error



Diagnosis = Normal ECG

Description: With correction of the voltage calibration (blue circles), the ECG is suggestive of left ventricular hypertrophy (yellow bars). However, it lacks a left axis deviation and fails to meet any of the voltage criteria (Sokolow-Lyon indices, Romhilt-Estes point score system, Cornell voltage criteria) for true LVH.



Voltage criteria for LVH

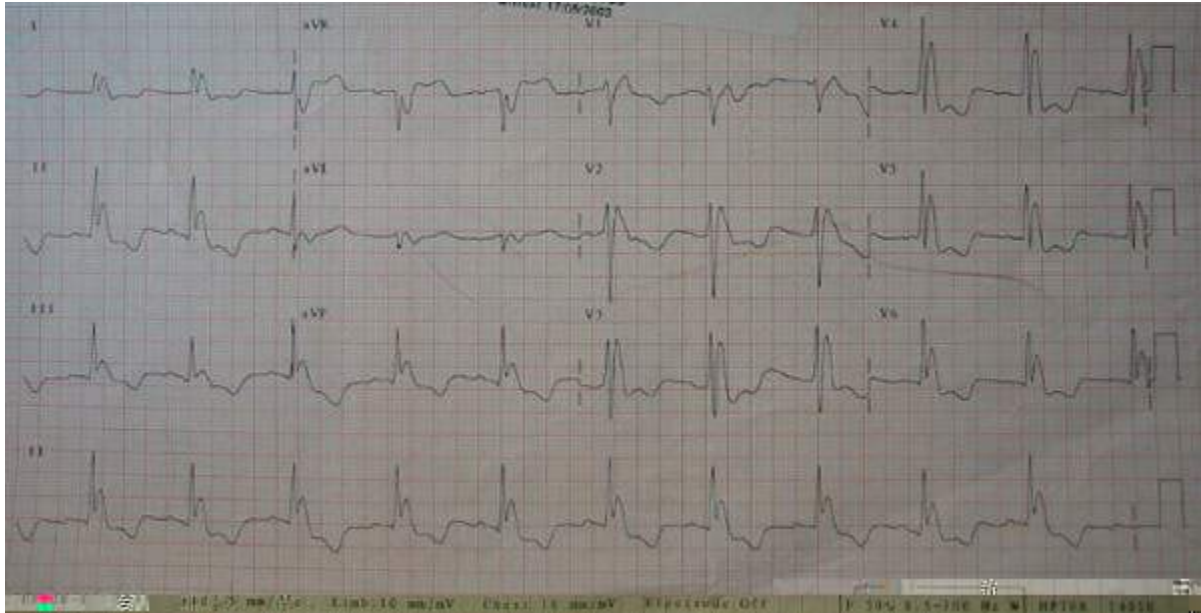
There are a variety of voltage criteria used to identify LVH, with specificities that are generally good (86 - 100%) but with poor sensitivities (1.5 - 55%). They include:

- S wave in V1 + R wave in V5 or V6 > 35 mm if age > 40yo, > 40 mm if age 30 to 40yo, > 60 mm if age 16 to 30yo (Sokolow-Lyon indices; sensitivity 40%, specificity 95%) (yellow bars).
- R wave in I + S wave in III > 25mm
- R wave in aVL > 11mm
- R wave in aVF > 20mm
- R wave in V5 or V6 > 26mm

ECG – Case 3

Question:

List 3 measures that are used to manage the condition indicated by the following ECG.



Answer:

Diagnosis = Hypothermia

Management:

7. Warm air blanket; e.g. Bair hugger
8. Warmed IV fluids
9. Warmed, humidified oxygen

Depending upon the severity of the hypothermia and the stability of the patient's condition, additional therapeutic modalities include warm fluid gastric lavage, warm fluid bladder irrigation, warm fluid peritoneal lavage, dialysis, endovascular warming catheter and cardiopulmonary bypass.

Rationale

Description

Borderline sinus bradycardia at 60bpm

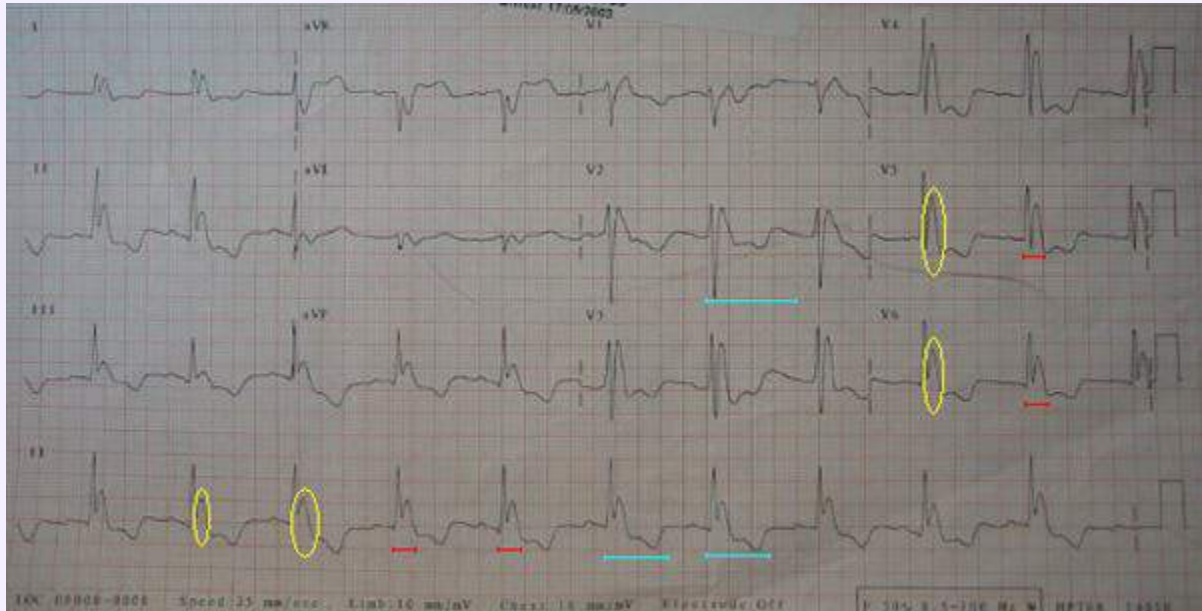
Normal axis

Prominent J-waves (Osborne waves – yellow circles) which indicate severe hypothermia (the height of the J-waves roughly correlates with the severity of the hypothermia).

Widened QRS complex (red bars), predominantly due to the J-waves

Widened QT segment (blue bars)

The PR segment is also often prolonged in hypothermia, but not in this case



ECG – Case 4

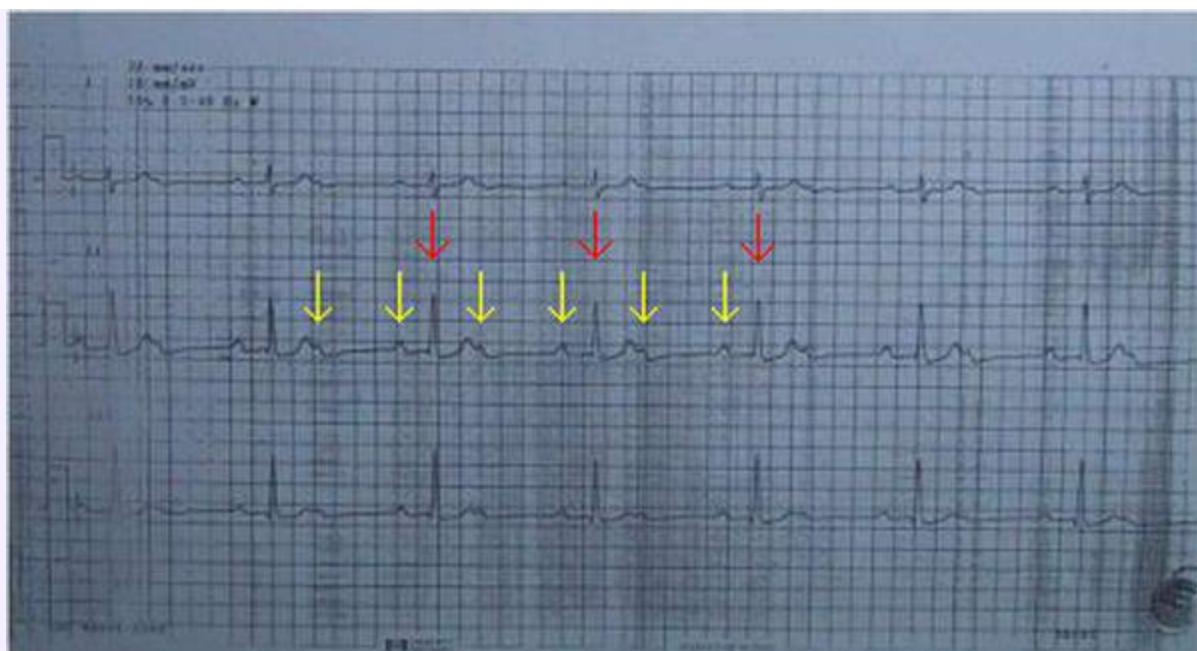
Question:

What associated pathology would you check for given the features of this ECG?

Answer:

Diagnosis = Mobitz type II 2nd degree heart block with 2:1 block

Associated pathology: Evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)



Description:

A normal morphology QRS complex (red arrows) follows every second P wave (yellow arrows) at regular intervals.

The P waves are spaced at regular intervals and are of normal morphology (as they originate from the sinus node)

The ventricular rate is approximately 40bpm

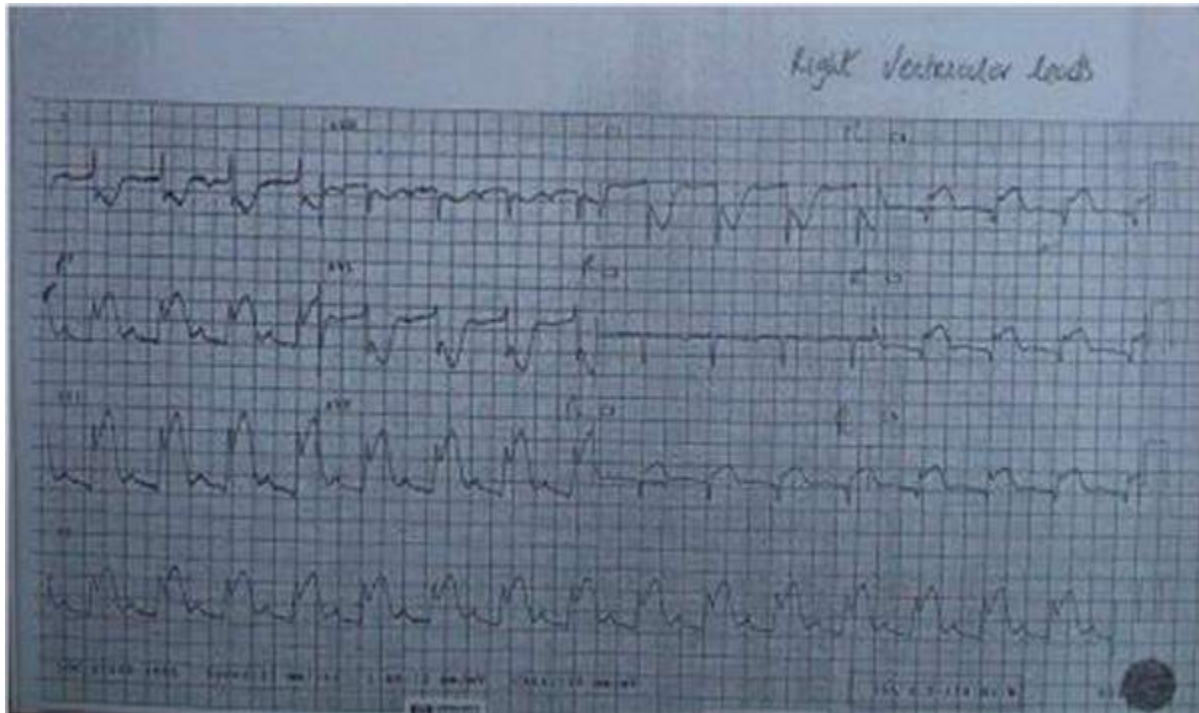
The axis is normal

There is no evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)

ECG – Case 5

Question:

What are the principles of managing this condition?



Answer:

Diagnosis = Right ventricular acute myocardial infarct with posterior extension and first degree heart block

Principles:

9. Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.
10. Hypotension is common and treated with volume resuscitation. Once euvolaemic, dobutamine may benefit. Cannot use CVP to guide volume status as it is elevated due to a failed right ventricle.
11. Analgesia – avoid nitrates, which can precipitate severe hypotension
12. Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)

Description

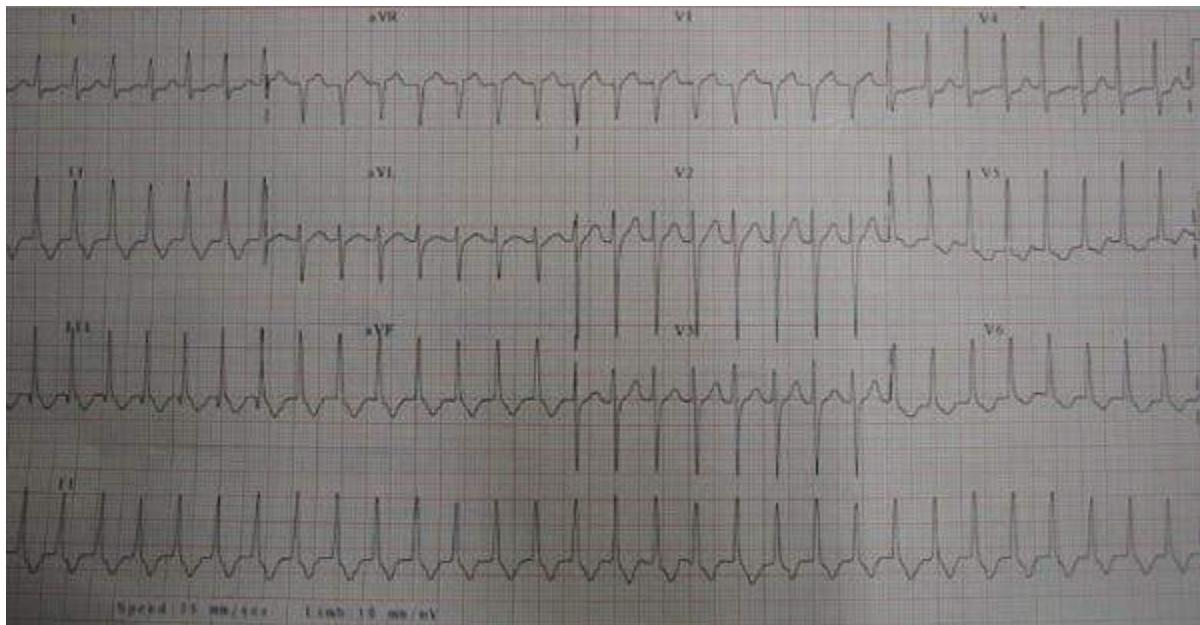
Significant ST elevation with hyperacute T waves in the inferior leads (II, III and aVF; yellow circles). Any inferior ischaemic event should prompt a search for

- A heart block – in this case there is a 1st degree heart block (green bars)
- A right ventricular AMI, especially if the ST elevation in lead II is higher than lead II, by performing a right ventricular ECG (red ellipse) where V 1 – 6, or just V4 alone, are placed in a mirror image position to their usual place on the chest and labelled V1R – V6R. The V4R to V6R leads (blue circles) demonstrate a similar appearance to a lateral AMI, but as they lie over the right ventricle, reflect an RV infarct.
- A posterior AMI (white ellipse) – flip the ECG over and bottom edge up and the waveform will look like a typical ST elevation AMI, or, perform a 15 lead ECG where leads V7 to V9 continue around from V6 to the posterior aspect of the chest.

ECG – Case 6

Question:

List 4 methods of treating this arrhythmia.



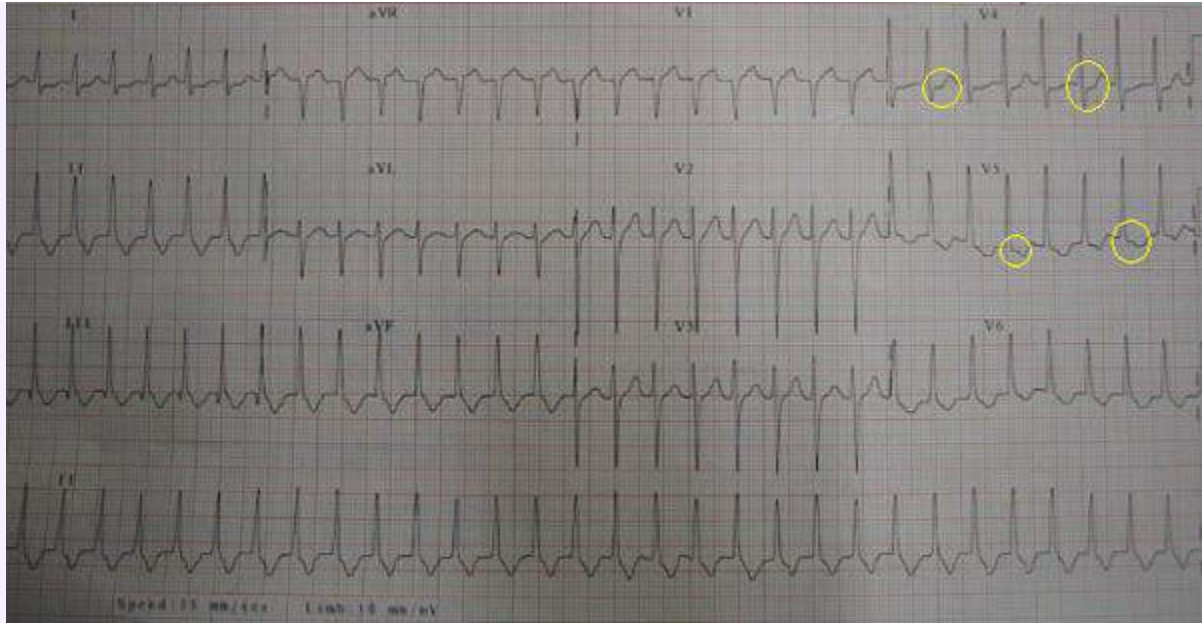
Answer:

Diagnosis = SVT (AVNRT)

Treatment

- Synchronised cardioversion (If hypotensive, evidence of cardiac ischaemia, evidence of heart failure or failed drug therapy. Potentially harmful if the SVT is due to digoxin toxicity.)
- Vagal manoeuvre – e.g. carotid massage, facial cold water immersion, Valsalva manoeuvre
- Adenosine IV in increments of 6mg to a maximum of 18mg, as a rapid bolus
- Verapamil 5mg IV over 1 – 2 minutes, unless accessory pathway (AVRT – see below) suspected

Additional alternatives include IV propranolol 0.5 – 1mg IV over 1 minute repeated every 5 minutes, metoprolol 5mg over 1 – 2 minutes every 5 minutes and external overdrive pacing at the SVT rate + 40bpm for 10 beats at 120mA.



Description

A regular narrow complex tachycardia with a ventricular rate of approximately 180bpm (therefore less likely to be atrial flutter, which usually runs at 150 or 300bpm)

There are no visible P waves, suggesting that this is an AV nodal re-entrant (AVNRT) SVT.

An AV re-entrant (AVRT) SVT is composed of an accessory pathway and the AV node, which requires the electrical impulse to travel between the two; orthodromic if it travels from AV node to accessory pathway and antidromic in the opposite direction. The resultant P wave is therefore usually seen after the QRS complex; i.e. the retrograde P wave, which shows up as a small negative deflection between the QRS complex and the T wave, or as a dent in the upstroke of the T wave. However, it may be difficult to confidently differentiate an AVRT from an AVNRT and it would make you less enthusiastic about using verapamil for chemical cardioversion.

ECG – Case 7

Question:

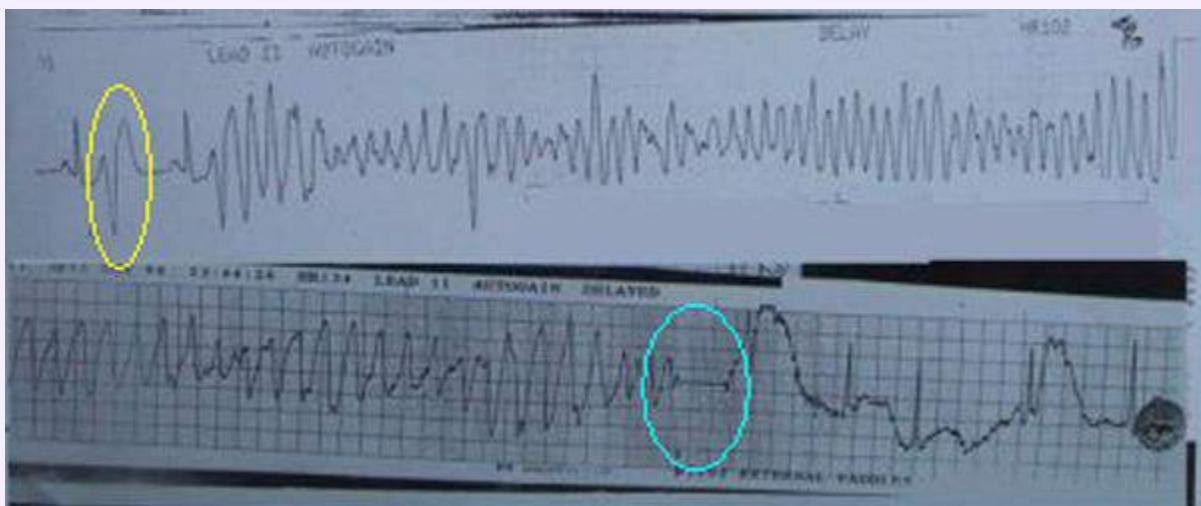
Please interpret the sequence of events in this rhythm strip. What underlying ECG deficit would you look for?



Answer:

Diagnosis = VPC resulting in R-on-T induced Torsades de pointes (polymorphic VT) at the start of the upper rhythm strip and subsequent cardioversion near the middle of the lower rhythm strip. There is no evidence of a large voltage spike prior to the cardioversion, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of $MgSO_4$.

I would look for a prolonged QT segment on the post reversion ECG. It is not evident on this strip.



Description

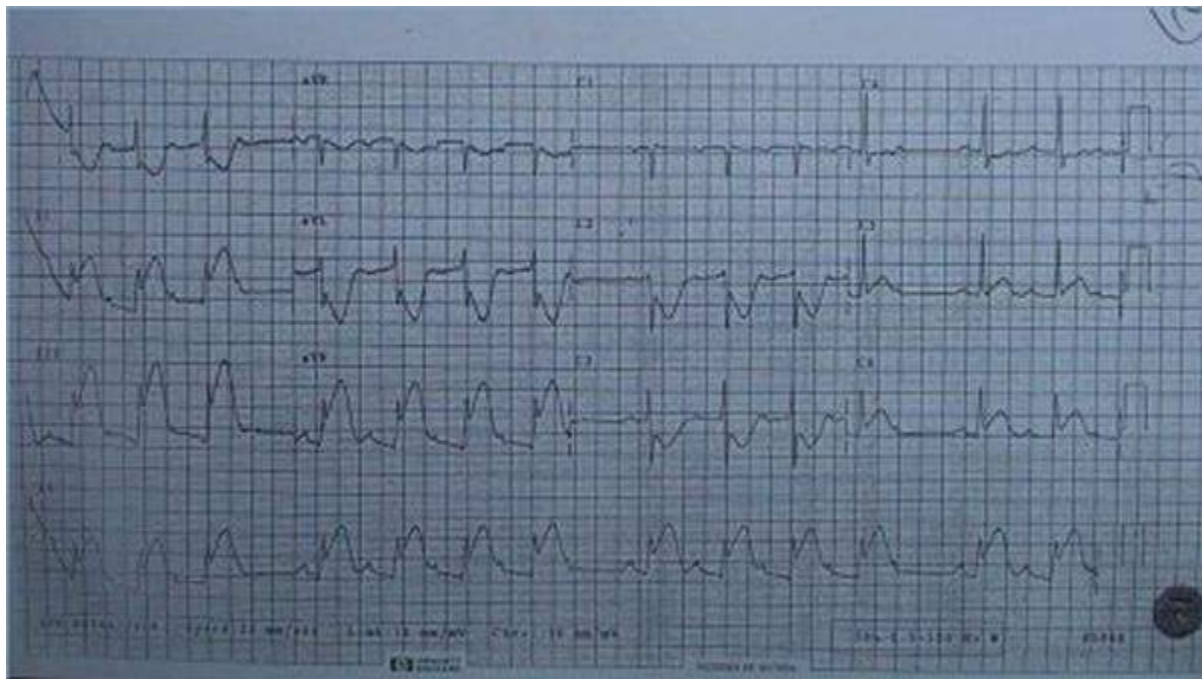
The upper rhythm strip demonstrates a VPC (yellow circle) occurring on top of the T wave of the preceding QRS complex. It probably recurs after the second QRS complex, as polymorphic VT ensues which varies both in the height and width of the complexes.

Midway through the lower rhythm strip, the VT terminates and reverts to a narrow complex rhythm that does not have an obviously prolonged QT segment (See below). At the point that the polymorphic VT terminates (blue circle) there is no evidence of a large voltage spike, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of MgSO₄.

ECG – Case 8

Question:

What pathologies are demonstrated on this ECG? What ECGs would you perform next?



Answer:

Pathologies = Inferoposterior acute myocardial infarction with Mobitz type I block (Wenkebach phenomenon)

The next ECGs: A right ventricular lead ECG, to exclude an RV infarct and a 15 lead ECG to confirm the presence of a posterior AMI.



Description

Significant ST elevation with hyperacute T waves in the inferior leads (II, III and aVF; yellow ellipses)

ST depression with inverted T waves, suggestive of a posterior AMI, in leads V2 and V3 (white ellipses)

The rhythm strip demonstrates a PR segment that lengthens progressively (blue bars) until a P wave fails to conduct through to the ventricles (blue arrow). This cycle repeats at a regular interval; in this case, every 5th P wave fails to conduct.

Remember, any inferior ischaemic event should prompt a search for:

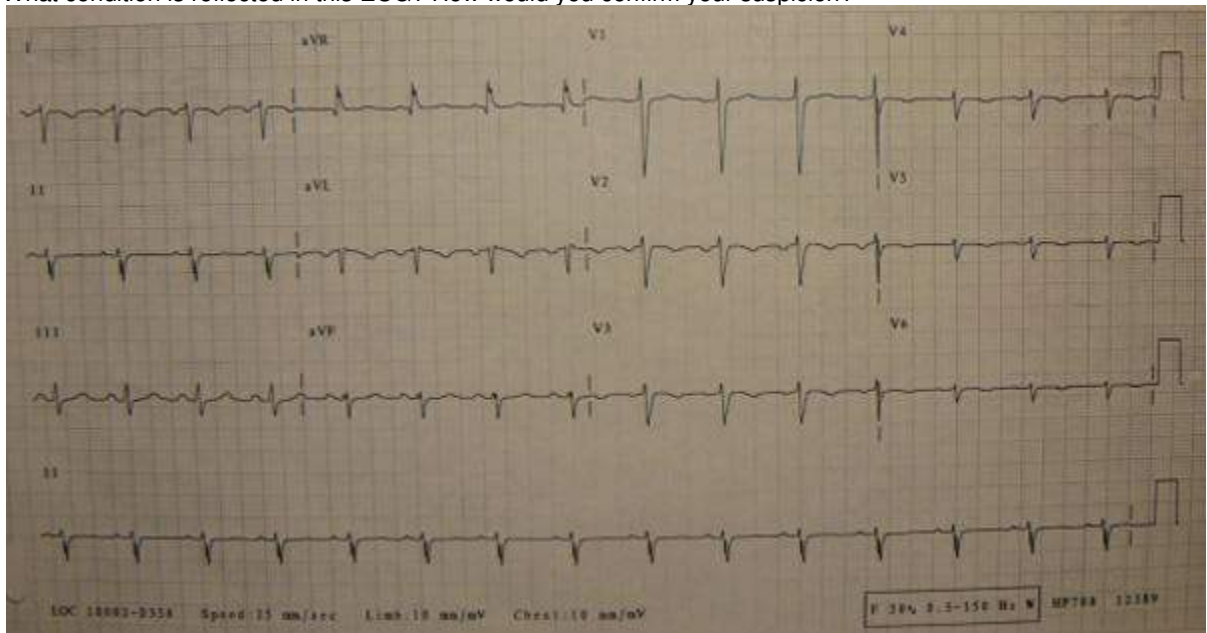
- A heart block – in this case there is a 1st degree heart block
- A right ventricular AMI, especially if the ST elevation in lead II is higher than lead III, by performing a right ventricular ECG where V1 – V6, or just V4 alone, are placed in a mirror image position to their usual place on the chest and labelled V1R – V6R. The V4R to V6R leads demonstrate a similar appearance to a lateral AMI, but as they lie over the right ventricle, reflect an RV infarct.
- A posterior AMI – flip the ECG over and bottom edge up and the waveform will look like a typical ST elevation AMI, or, perform a 15 lead ECG where leads V7 to V9 continue around from V6 to the posterior aspect of the chest.

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- ECG – Case 9

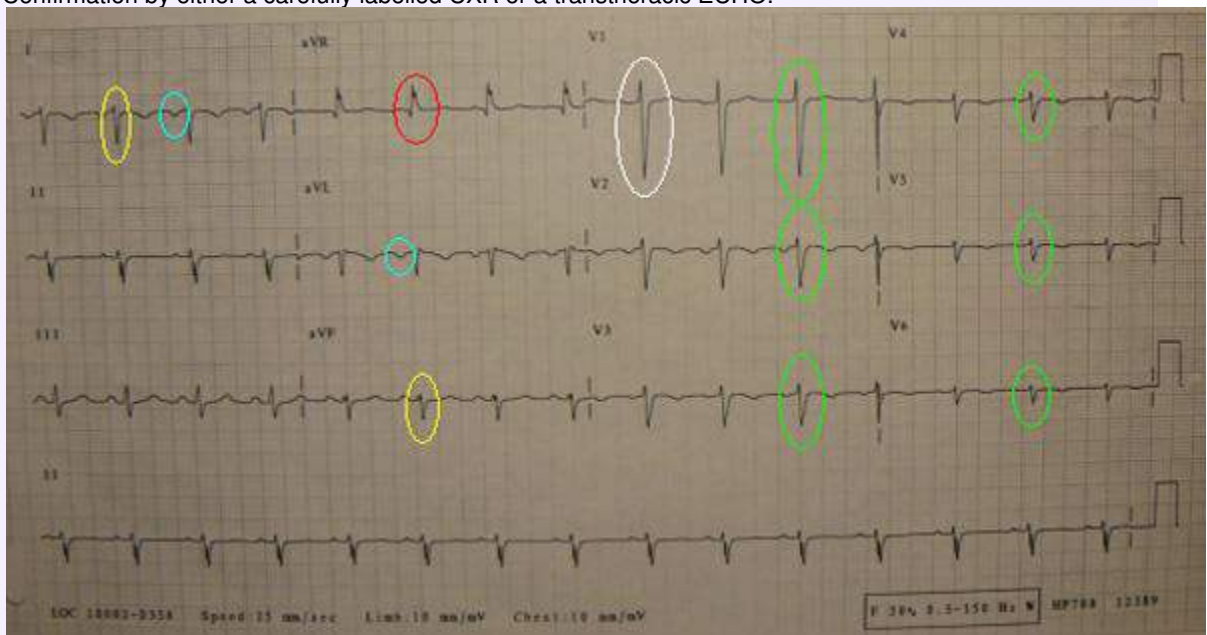
- **Question:**

- What condition is reflected in this ECG? How would you confirm your suspicion?



- **Answer:**

- Diagnosis = Dextrocardia
- Confirmation by either a carefully labelled CXR or a transthoracic ECHO.



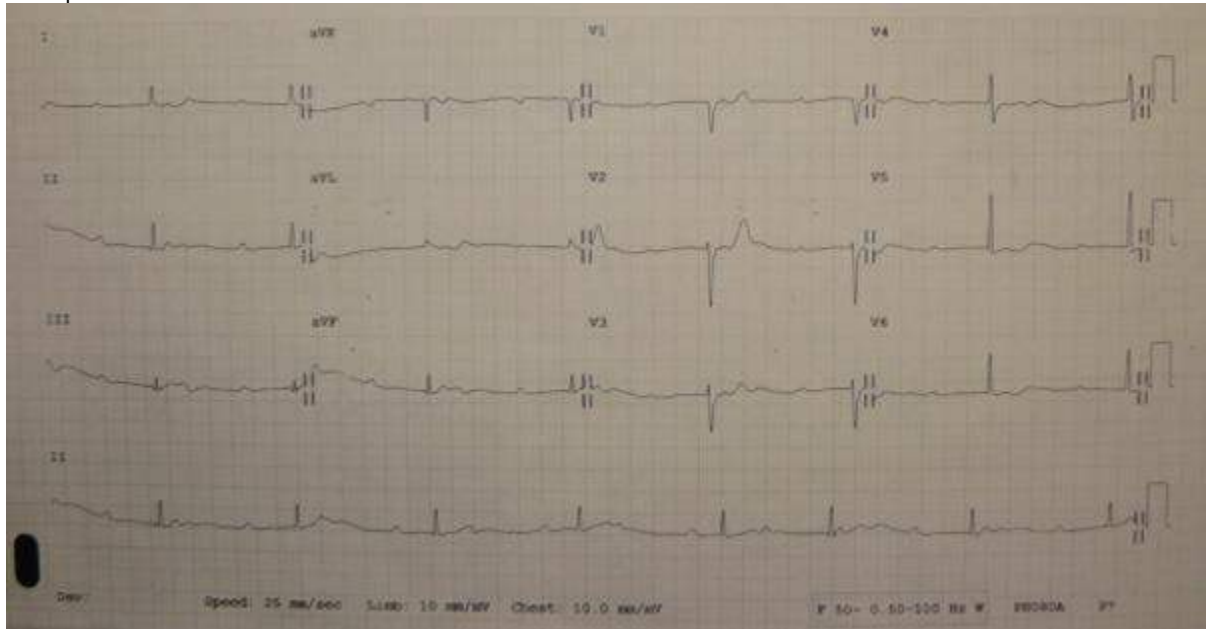
- **Description**

- Extreme right axis (yellow ellipses)
- Negative deflection P waves in leads I and aVL (blue ellipses)
- QRS in aVR (red ellipse) looks like a normal aVL complex
- Presence of an RV1 (white ellipse)
- Poor R wave progression from V1 to V6

- **ECG – Case 10**

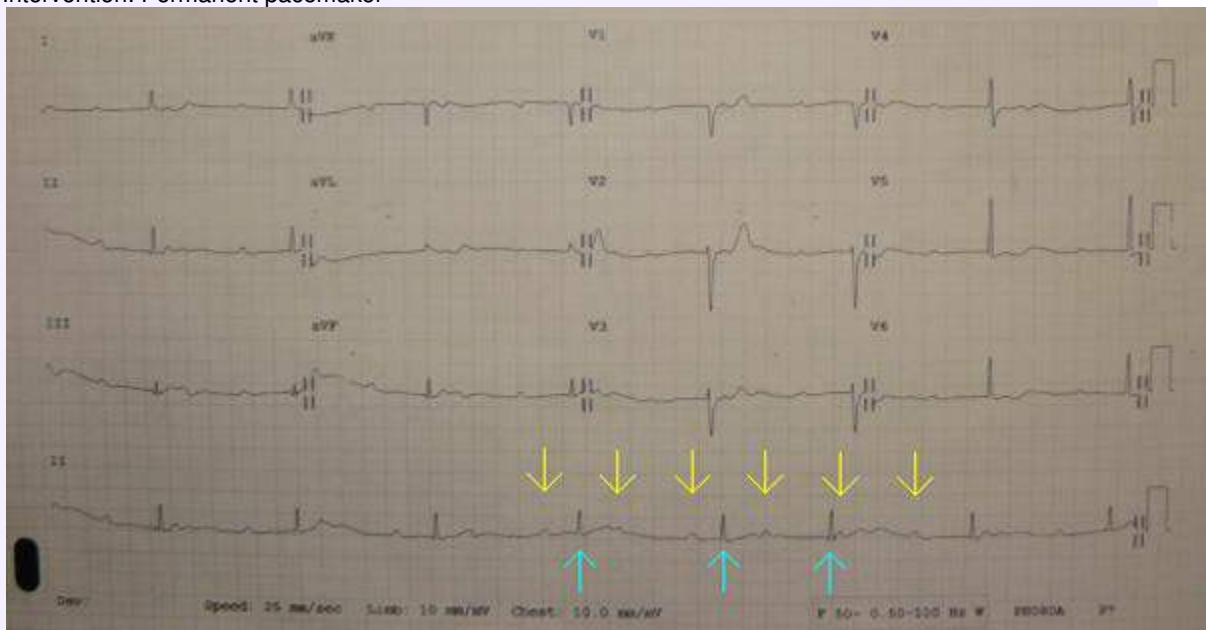
- **Question:**

- What physiological disturbance might you expect as a result of this ECG? What definitive intervention may be required?



- **Answer:**

- Diagnosis = Complete heart block
- Physiological disturbance: Hypotension
- Intervention: Permanent pacemaker



- **Description**

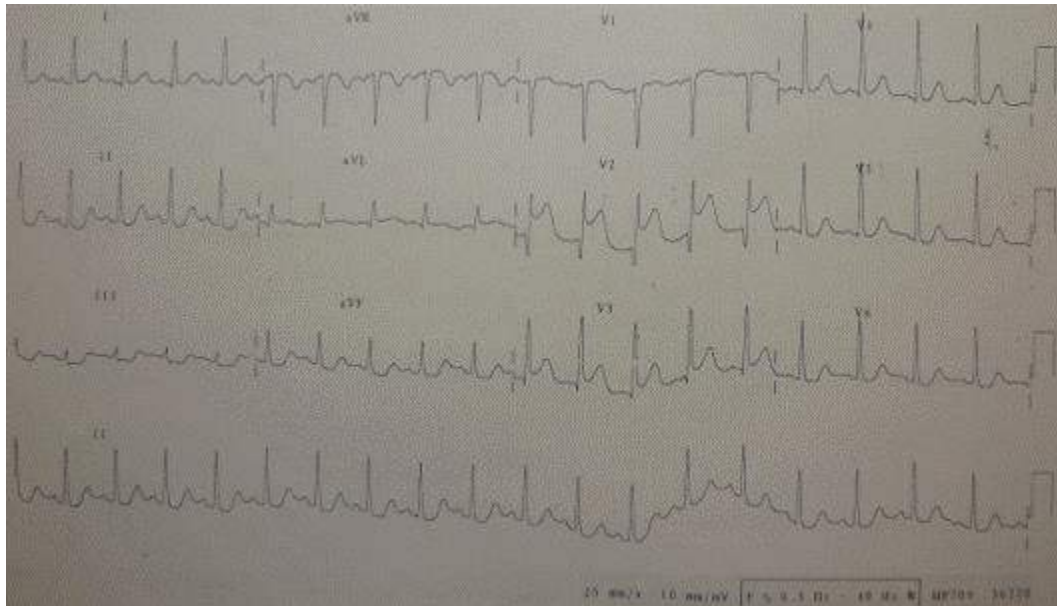
- Normal morphology P waves occurring at a regular interval (yellow arrows) and independent of the occurrence of QRS complexes (blue arrows)
- The ventricular rate is approximately 50bpm and is probably junctional in origin (narrow complex)

- No evidence of an inferior ischaemic event on this ECG (Always look for this when you identify a heart block pattern!)

ECG – Case 11

Question:

Outline your management of a patient who develops the following ECG.



Answer:

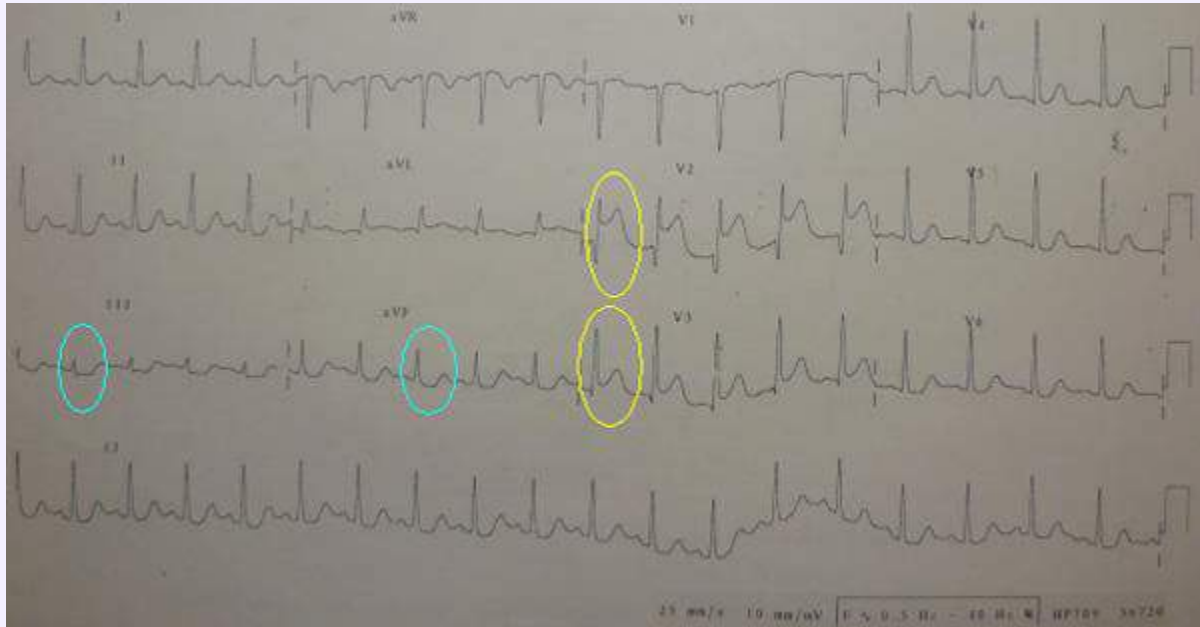
Diagnosis = Anteroseptal AMI with reciprocal changes in the inferior leads

Management:

19. Resuscitation as required

- support oxygenation and ventilation
 - support blood pressure with IV fluid and, if necessary, an inotrope such as adrenalin
- Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.
- Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)
- Analgesia – sublingual nitrate, IV morphine
- IV heparin for a minimum of 48 hours, aiming for an aPTT of 60 - 90s
- β -blockade aiming for a HR of 60 – 90bpm
- Screen for remediable risk factors
- Monitor for complications of an AMI, especially heart failure in this context.
- Start a myocardial remodeller, e.g. ACE inhibitor or carvedilol, once that patient is stable.

Rationale:



Description

Significant ST segment elevation with hyperacute T waves in V2 and V3 (yellow ellipses) and ST depression in leads III and aVF.

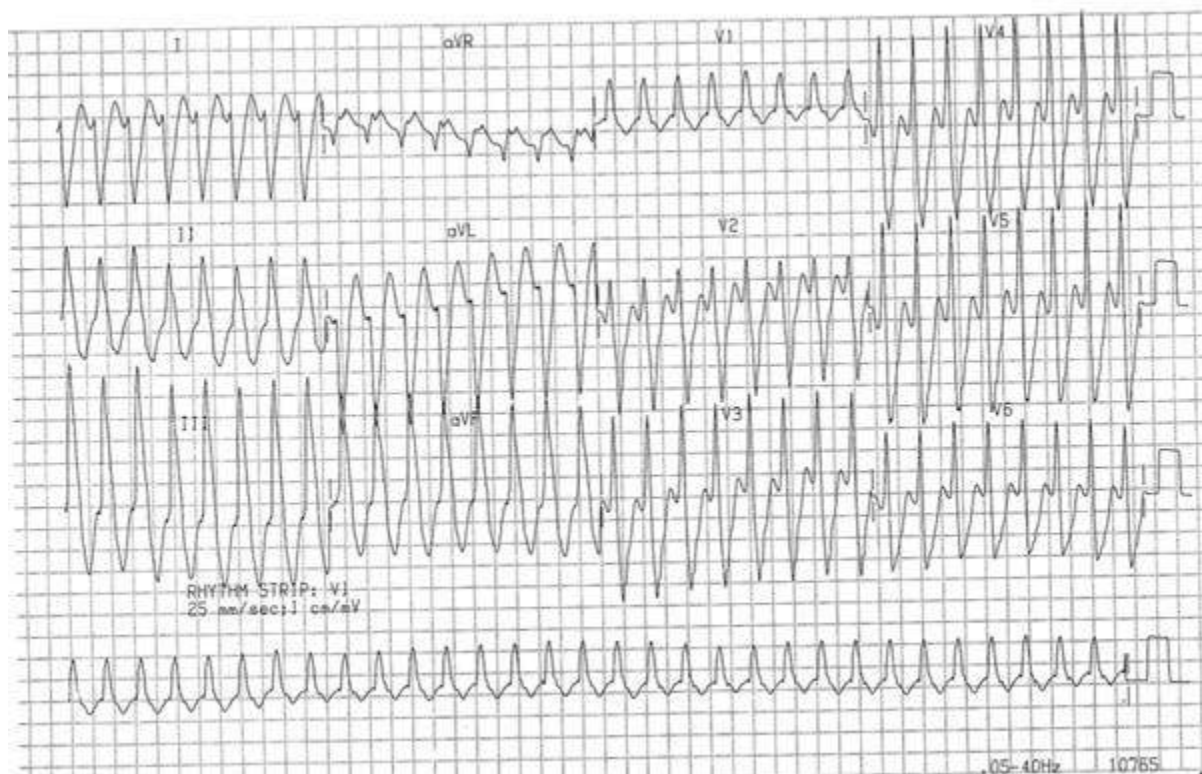
This pattern suggests an LAD lesion, which is likely to be proximal.

The lateral region is unaffected, suggesting that the circumflex has been spared and therefore the left main artery is not involved.

ECG – Case 12

Question:

What ECG features would you use to determine the source of this tachyarrhythmia?



Answer:

Diagnosis = Broad complex tachycardia, likely to be an SVT with aberrant conduction.

Features used to differentiate between a VT and an SVT with aberrant conduction

VT

- Concordance – i.e. all of the QRS complexes point in the same direction, either positive or negative
- Fusion beats – an atrial impulse is conducted successfully through to the ventricle and merges with a VT wave, producing a complex with a bizarre broad morphology
- Capture beats - an atrial impulse is conducted successfully through to the ventricle, resulting in the appearance of a normal P-QRS complex amidst the VT activity
- AV dissociation – P waves may be visible intermittently, but are not conducted effectively
- Leftward axis
- QRS > 140ms (3½ small boxes)

SVT with aberrance

5. Essentially the opposite of VT, although the QRS duration may be similarly prolonged, particularly if there is a pre-existing or rate-related BBB
6. If the broad complex tachyarrhythmia is irregular, then the decision is between VF (no output) and AF with aberrancy (may be hypotensive)

Description

A regular, broad complex tachyarrhythmia at approximately 160bpm

Right axis, possibly due to a rate-related BBB, consistent with an SVT with aberrancy

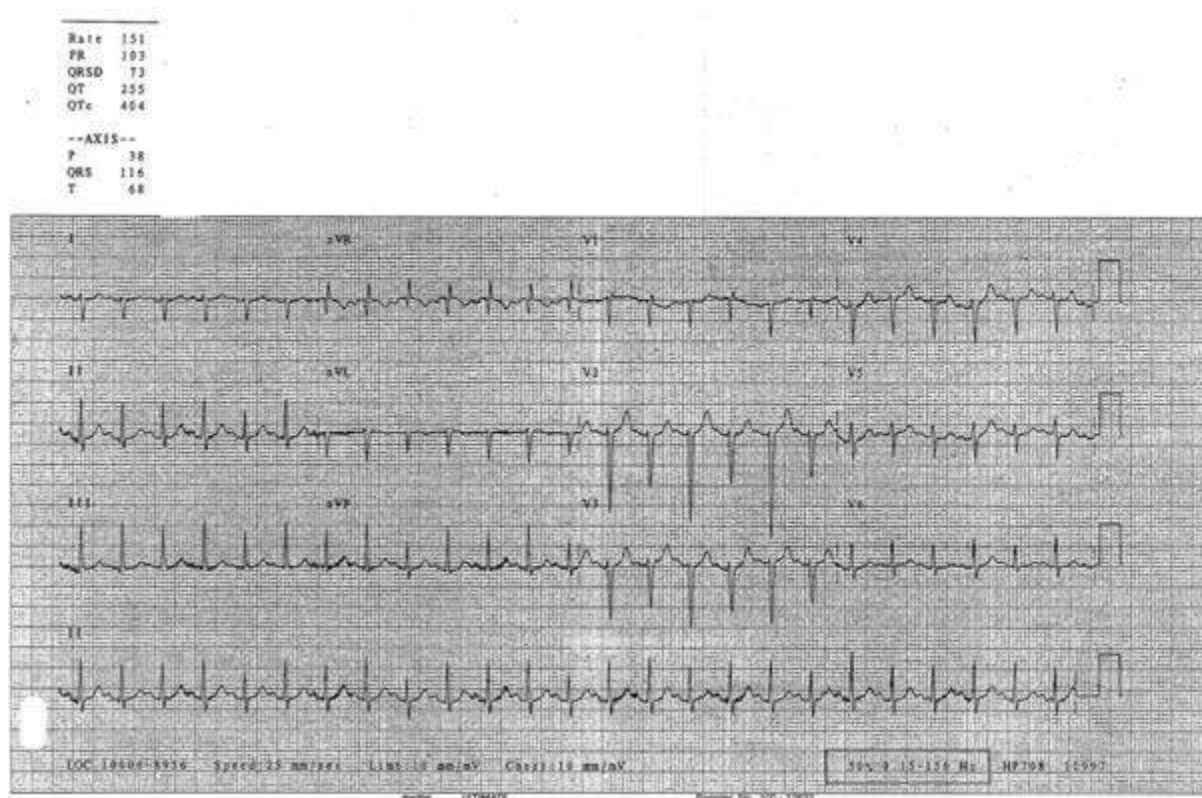
No visible P-waves, fusion beats or capture beats

Absence of a visible P-wave suggests an AVNRT

ECG – Case 13

Question:

How would you confirm the diagnosis? What therapeutic intervention would you consider for a hypotensive patient with the following ECG?

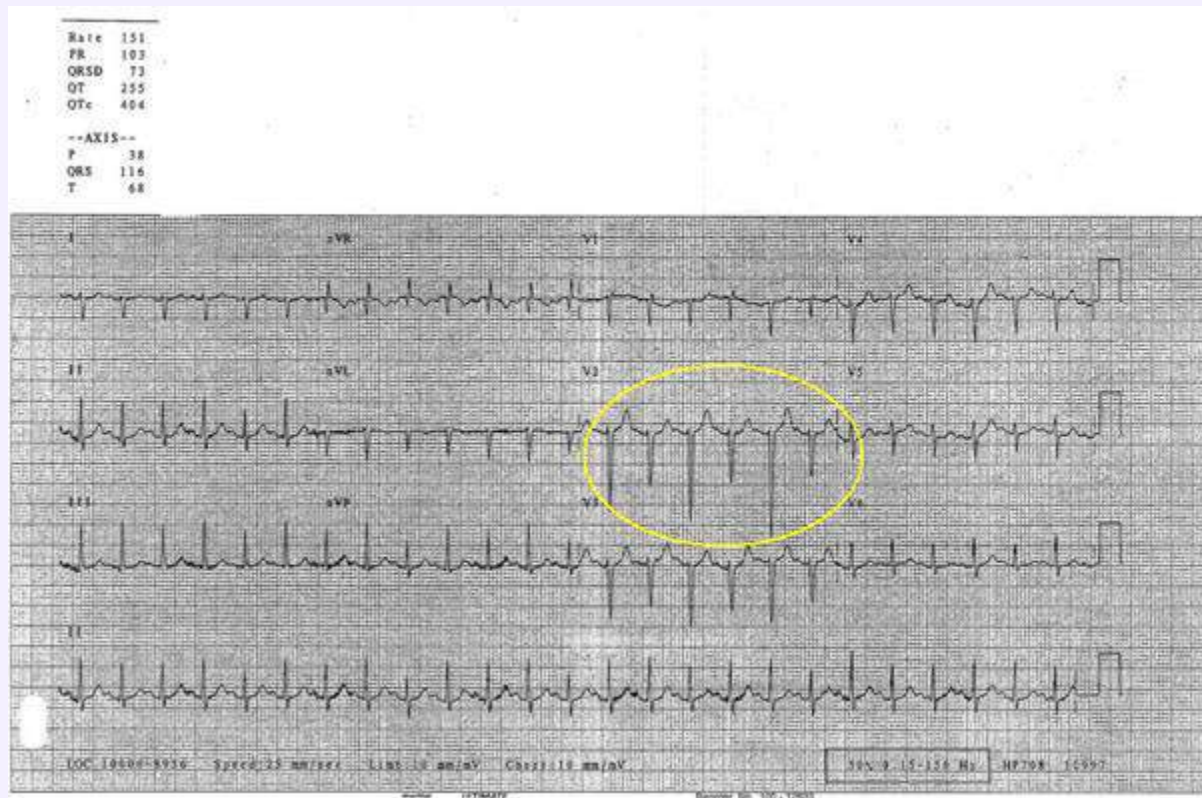


Answer:

Diagnosis = Electrical alternans, pathognomonic of a pericardial effusion

Confirmatory investigation: Transthoracic ECHO

Therapeutic intervention: Pericardiocentesis. If recurrent, a pericardial window may be required.



Description

Sinus tachycardia at approximately 150bpm with a rightward axis

Electrical alternans is demonstrated most clearly in leads V3 (yellow ellipse) and V4

The PR and QT segments are of normal duration

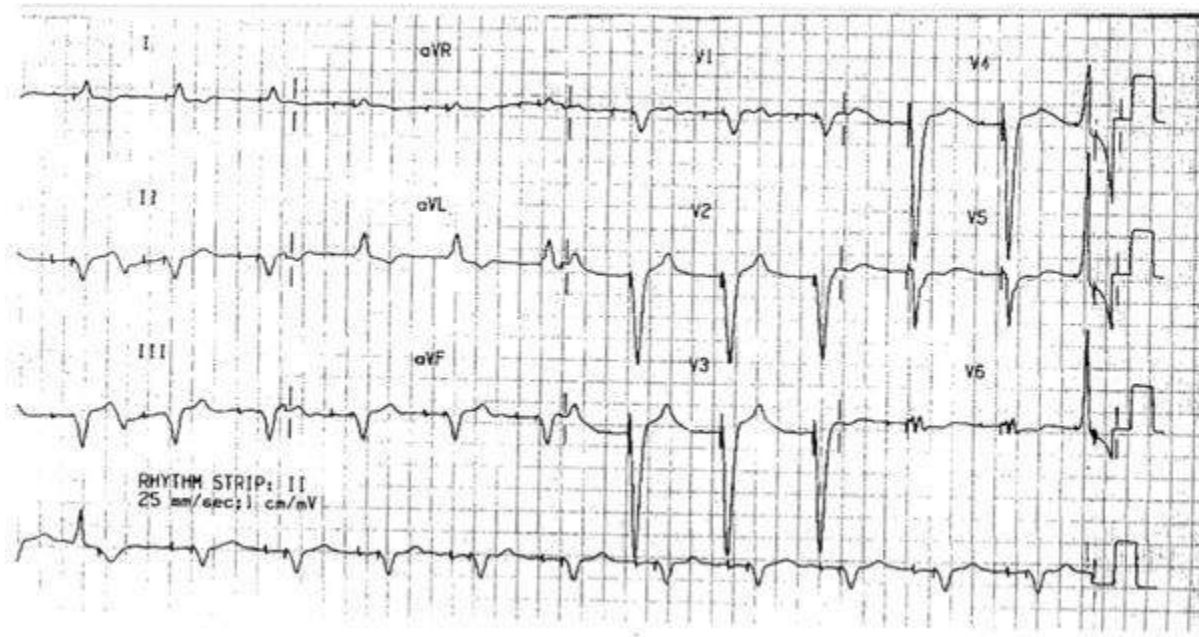
The QRS is narrow and of normal morphology

There are no ischaemic features

ECG – Case 14

Question:

List 6 causes of the following ECG abnormality.



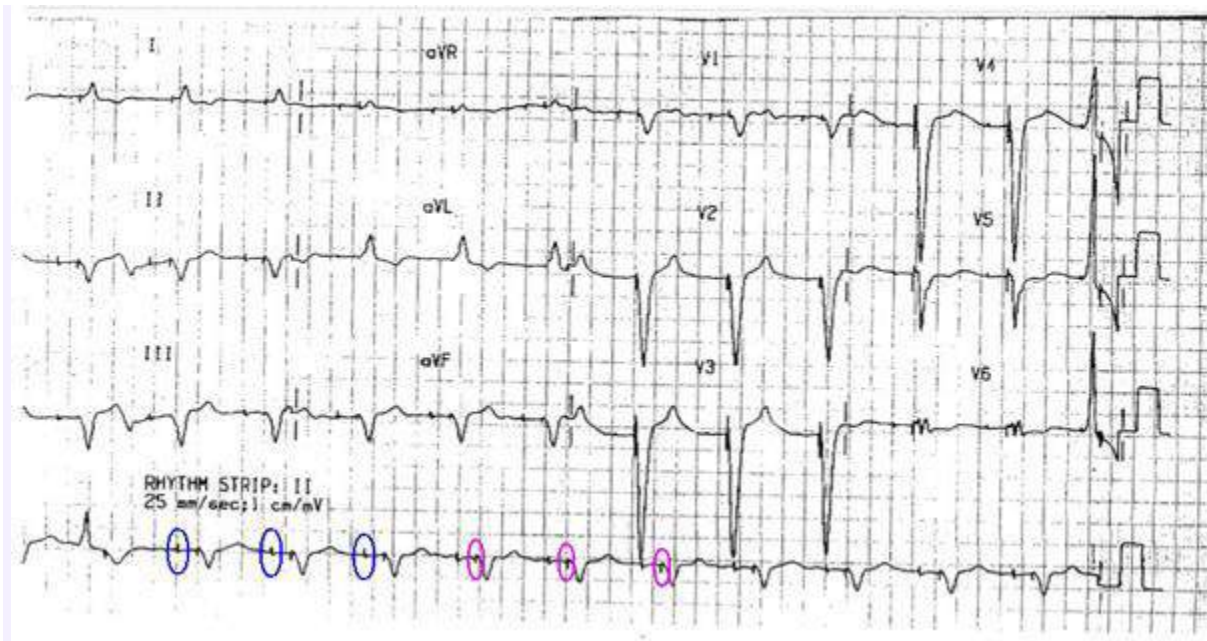
Answer:

Diagnosis = Failure of atrial lead capture in a dual lead pacemaker

Causes:

- Physiological failure – Pacemaker discharge occurs during the myocardial refractory period. (Resolved by reprogramming the pulse generator.)
- lead fracture
- fibrosis at the lead tip
- hyperkalaemia
- hypoxaemia
- myocardial ischaemia

Also consider antiarrhythmic drug toxicity.



Description

Atrial pacing spikes (Blue ellipses) which do not result in a visible atrial impulse.

There are ventricular pacing spikes (Pink ellipses) consistently followed by a broad QRS complex, suggesting that the ventricular pacing wire is functioning properly.

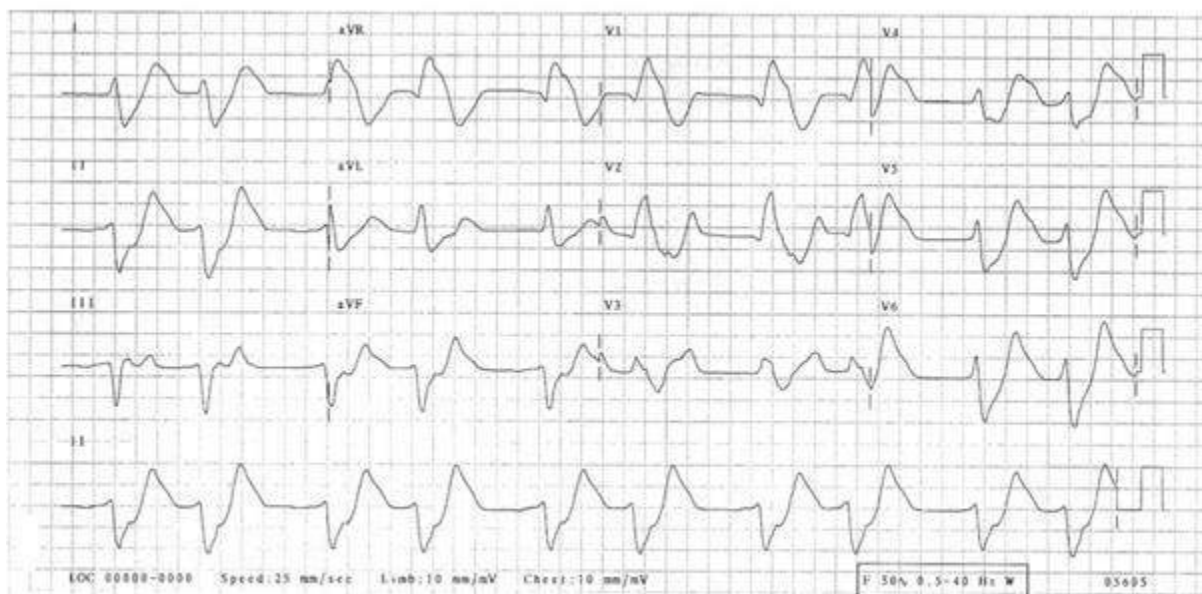
The pacemaker rate is approximately 80bpm.

There is a leftward axis, typical of a right ventricular pacing wire

ECG – Case 15

Question:

List the therapeutic interventions, along with an indication of time to effect and the mode of effect, for a patient with the following ECG



Answer:

Diagnosis = Hyperkalaemia

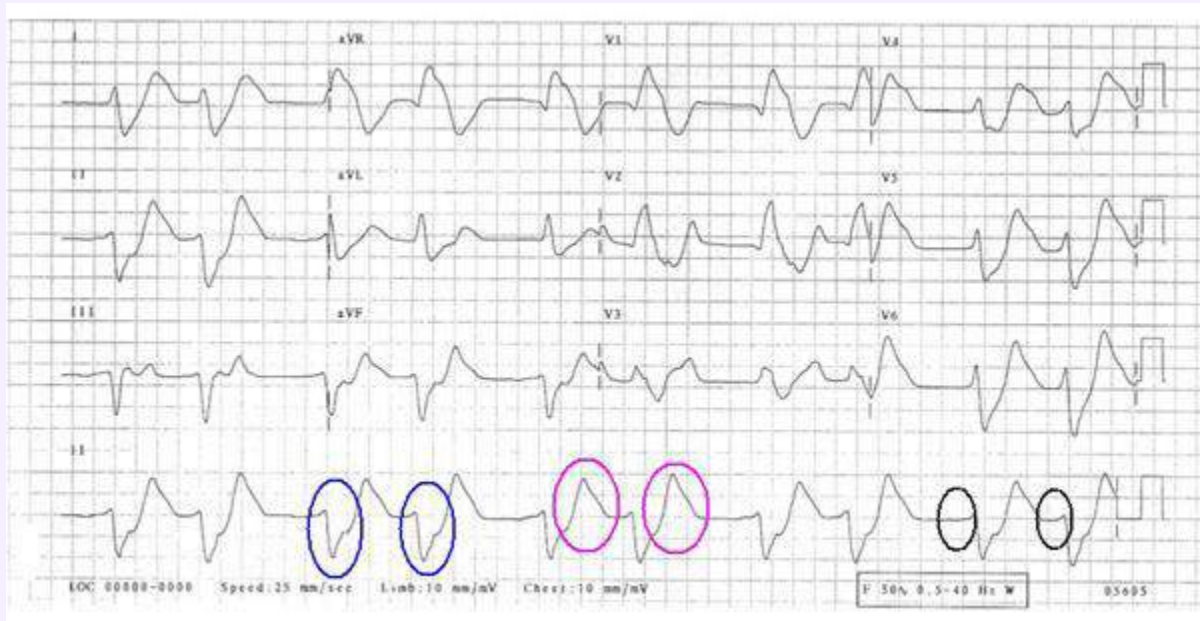
Therapeutic strategies

Therapy	Time to effect	Mode of effect
Calcium chloride 10mls 10%	Seconds to minutes	Stabilises myocardium from effect of hyperkalaemia. Avoid if digoxin toxicity suspected
0.5 – 1mEq/kg NaHCO ₃ 8.4% IV	Several minutes	Intracellular K ⁺ shift
50mls 50% Dextrose + 10U Actrapid insulin IV (Arguably, if the person is not a	20 – 40 minutes	Intracellular K ⁺ shift

diabetic, the dextrose challenge should stimulate sufficient native insulin to achieve the desired effect)		
Continuous nebulised salbutamol	20 – 40 minutes	Intracellular K ⁺ shift. (Better efficacy in paediatric population than adults)
Loop diuretic; e.g. frusemide 40 – 120mg IV with IV fluids to cover for the diuresis.	30 – 120 minutes	Enhanced renal excretion of K ⁺ (Potassium losing diuretic)
Polystyrene sulfonate salt; e.g. calcium or sodium resonium 30 – 45g PO/PR	1 – 3 hours	Ion exchange resin that bind K ⁺ and enhances GI elimination
Dialysis; K ⁺ free IHD, SLED, CRRT or peritoneal dialysis	Applied for several hours, but rapidity of effect related	Transfilter, or transperitoneal, K ⁺ removal

to blood
flow rate

Rationale:



Description

Bradycardia with a rate of approximately 60 – 65bpm

Absent / Flat P-waves (Black ellipses)

Broad QRS complexes with bizarre morphology (Blue ellipses)

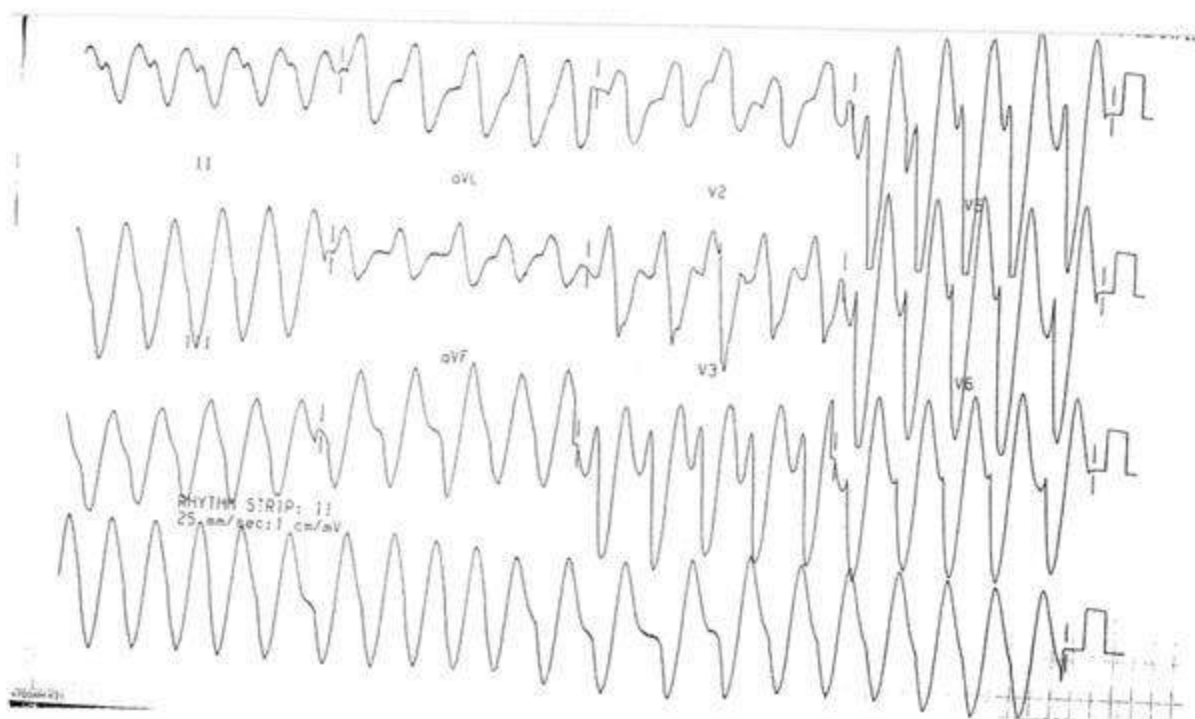
Tall, peaked T-waves (Pink ellipses)

Approaching sinusoidal waveform, which is a pre-asystolic rhythm

ECG – Case 16

Question:

A patient with a history of hypertension, depression and gout presents to the emergency department. Outline your management of the condition responsible for the following ECG.

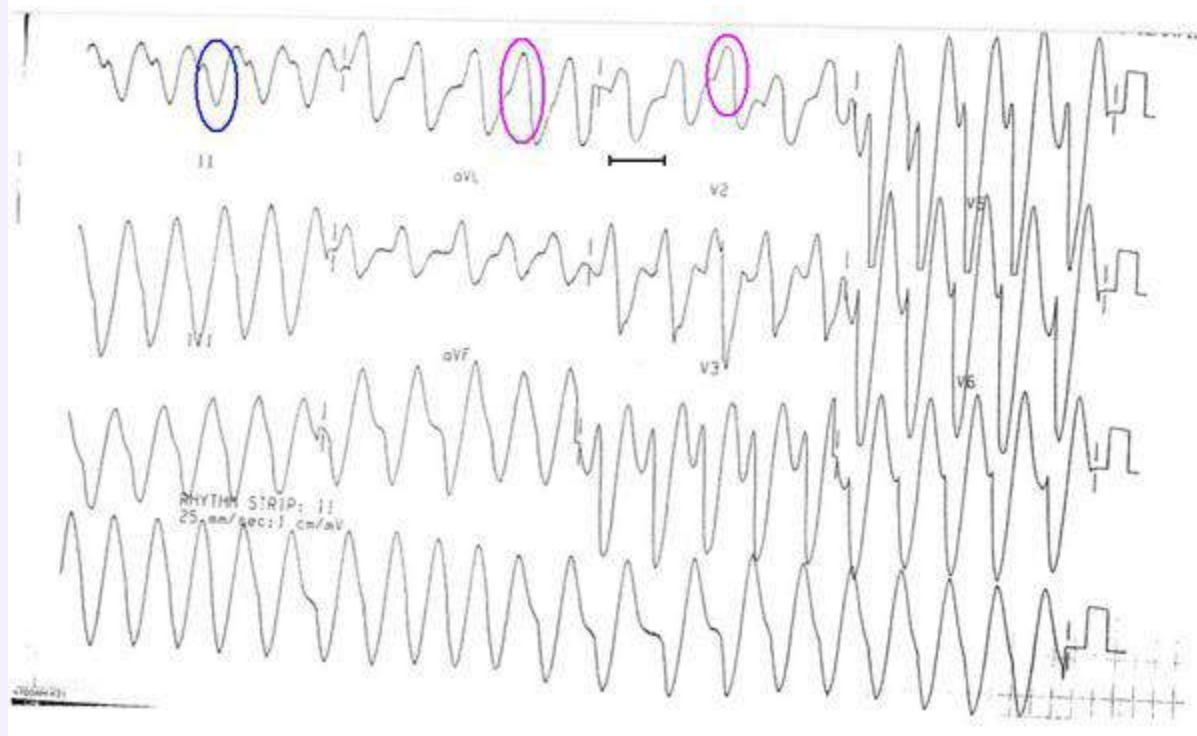


Answer:

Diagnosis = Tricyclic antidepressant toxicity

Management

19. Support oxygenation and ventilation
20. Support blood pressure with IV crystalloid. If significant hypotension, 1 – 2mEq/kg NaHCO₃ is indicated. If refractory, use noradrenalin IV infusion.
21. Treat arrhythmias (high risk if QRS >0.1s) with 1 – 2mEq/K NaHCO₃ IV, 1mg/kg Lignocaine IV and synchronised cardioversion.
22. Treat seizures (high risk if QRS >0.1s) with benzodiazepines. The role of phenytoin is controversial and not recommended by some authors.
23. 1 – 2mEq/K NaHCO₃ IV rapidly narrows the QRS complex width and reduces the risk of arrhythmias
24. Once the airway is secured, consider gastric lavage as the antimuscarinic effect often results in delayed gastric emptying and absorption of further drug can therefore be reduced
25. Consider using 20% intralipid IV, as TCADs are lipophilic
26. Full monitoring while QRS remains prolonged
27. If intentional, will require psychiatric review, once acute toxicity has resolved



Description

Broad complex, regular tachycardia

Prolonged QT interval (Black bar)

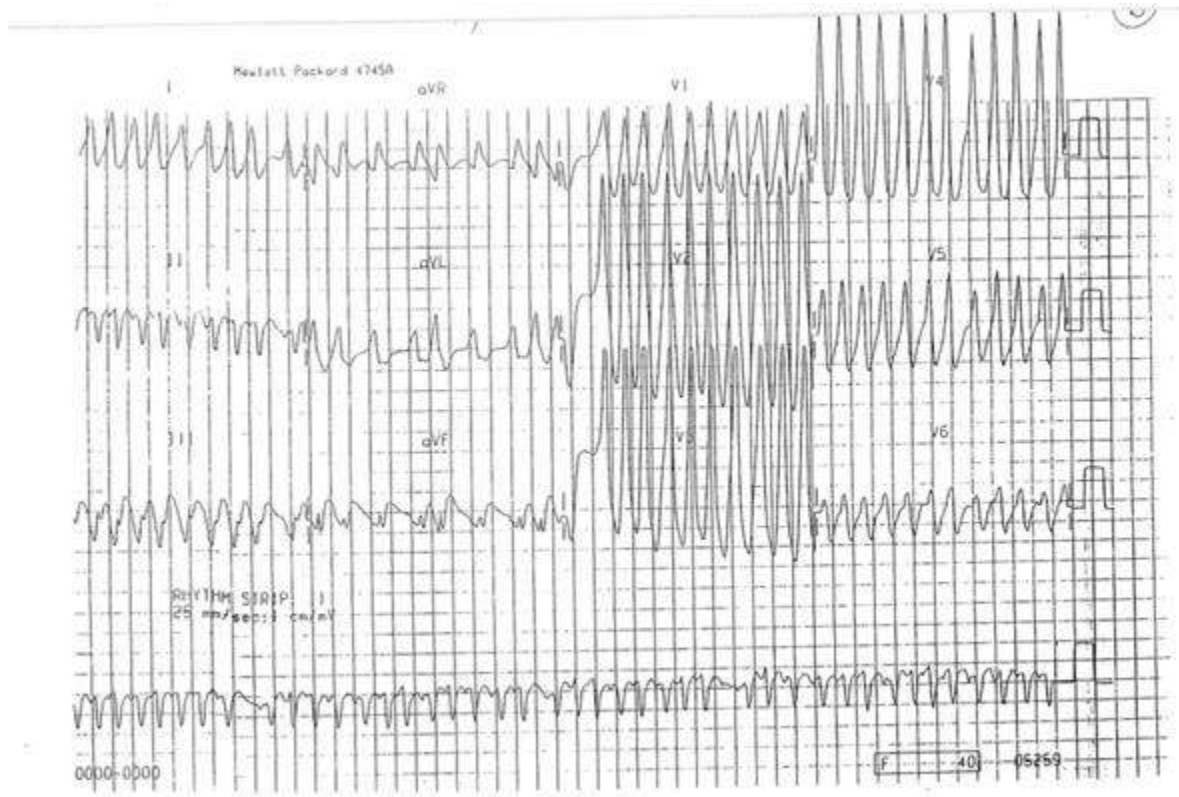
Deep S-wave in lead I (Blue ellipse)

Prominent R-wave in aVL or V1 (Pink ellipse)

ECG – Case 17

Question:

What are the treatment options for a normotensive patient with this ECG?



Answer:

Diagnosis = Wolff-Parkinson-White syndrome in atrial fibrillation with ultrarapid ventricular response

Treatment options:

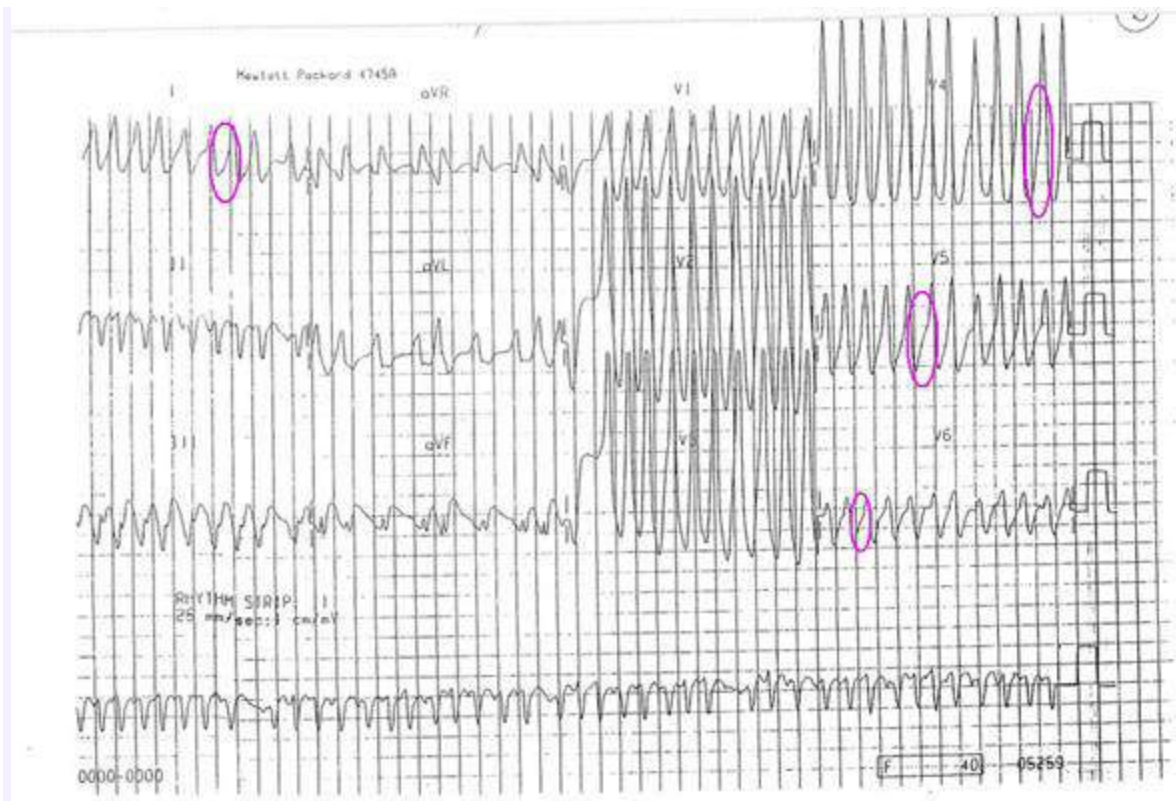
Pharmacological

7. Amiodarone
8. Procainamide
9. Flecainide

Electrical

3. Synchronised cardioversion

Avoid AV node blockers (verapamil, digoxin and β -blockers) which may accelerate the tachyarrhythmia



Description

Irregular tachycardia at approximately 300bpm

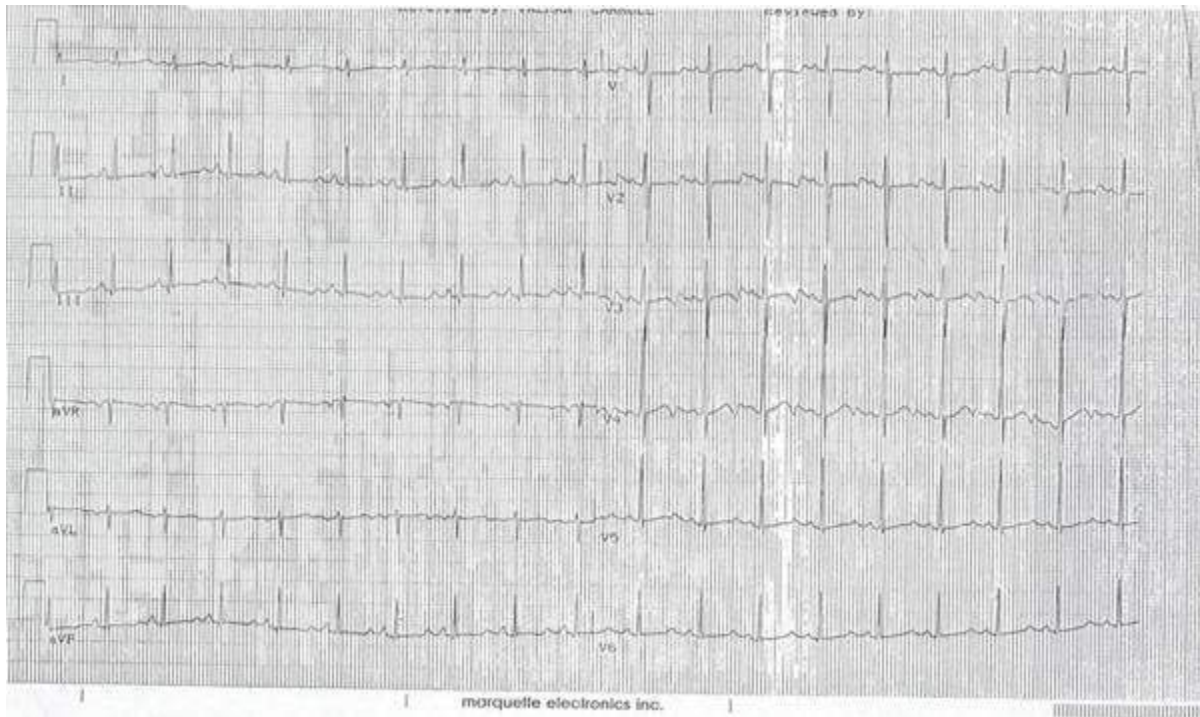
Slurred upstroke at the start of the QRS complex visible in several leads (Pink ellipses)

Difficult to determine the type (A-E) and therefore the location of the accessory tract, due to the rapidity of the tachycardia on this ECG. Obtaining a repeat ECG after the rate has been slowed would help

ECG – Case 18

Question:

List 7 causes of the following ECG appearance.



Answer:

- Electrolyte disturbances – hypoMg, hypoK, hypoCa
- Medication – Class Ia, Ic and III antiarrhythmics, macrolides, azole antifungals, antipsychotics, antidepressants, antihistamines
- Endocrinopathies – hypothyroidism, pheochromocytoma
- Cardiac disease – AMI, myocarditis
- Intracranial pathologies – ICH, CVA
- TPN
- Congenital conditions – Romano-Ward syndrome, Jervelle-Lang-Nielson syndrome



Description

If numerical data is available at the top of the ECG, one of the few to be taken on faith is the QTc, as it is tricky to calculate Bazett's formula under exam conditions. The normal QTc is < 440mSec. Alternatively, visually checking to see if the QT interval (Pink bar) appears to occupy more than half of the R-R interval (Blue bar) is a valid estimate of prolongation

Laboratory data case

These questions can provoke significant anxiety for candidates, especially for those of us who feel intimidated by maths. However, if practiced, these questions can be answered quickly, yielding valuable points and creating extra time for answering less cut and dry questions. In reality, there are only a few regularly used calculations and many cases follow common patterns that can be recognised once you have seen them a few times.

For anyone wishing to practice these types of questions, some good resources include:

- Mark Finnis' Biochemistry data set - http://www.icuadelaide.com.au/ss_finnis_notes.html
- "Data Interpretation in Critical Care Medicine"; Bala Venkatesh, T.J. Morgan, Chris Joyce; Elsevier
- "Practical intensive care medicine: *Problem solving in the ICU*." Charlie Corke. Butterworth-Heinemann, 2nd Ed.
- Crit-IQ - <http://www.crit-iq.com.au>.
- PACT (Patient-centred Acute Care Training) - The European Society of Intensive Care Medicine eLearning program, available at <http://www.esicm.org/>. Click on the "Education" tab and choose "PACT Programme" from the drop down menu.

Additionally, MRCP preparation books and online sources are fairly plentiful, although less tailored towards the ICU exam format.

Tips for the laboratory data questions

11. Read the lead-in scenario carefully. Every word is carefully placed in the stem; not to trap you, but rather to guide you towards a limited differential list. Often you can get a feeling from the stem for what diagnosis the subsequent numbers are going to result in.
12. Don't provide long-winded explanations in your answers. Succinct bullet points will buy you some time and gain you the same marks, along with a degree of credit with the examiner who has to wade through thirty or so scripts. (Note: In the cases that follow, a fuller answer than might be required by a question in the exam is provided, in order to explain the thought processes that derive the answer.)
13. Try to quantify deficits; e.g. mild, moderate, severe, life threatening. It suggests clarity and your ability to prioritise; both important consultant qualities.
14. Some of the calculations used have several variations; e.g. calculated osmolality, anion gap, corrected Na^+ in hyperglycaemia. Use whichever one you are most comfortable with.
15. If an extra value seems to have appeared amongst otherwise routine data (e.g. iCa^{2+} , uric acid, WBC differential), question why it is there, as it is unlikely to be extraneous.

Useful calculations

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO})$. Normal 6-15 mmol/L
- $\text{Corrected Na} = \text{Na} + (\text{Glucose}/3)$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Acid-base corrections:

Acid-base disorder	Rule (kPa)	Rule (mmHg) *
Primary Acute respiratory acidosis	HCO_3^- increase 1 mmol/L per 1.3 kPa rise in PaCO_2 above 5 kPa (up to 30 mmol/L)	HCO_3^- increases 1 mmol/L per 10 mmHg rise in PaCO_2 above 40 mmHg (up to 30 mmol/L)
Primary Chronic respiratory acidosis	HCO_3^- increases 4 mmol/L per 1.3 kPa rise in PaCO_2 above 5 kPa (up to 36 mmol/L)	HCO_3^- increases 4 mmol/L per 10 mmHg rise in PaCO_2 above 40 mmHg (up to 36 mmol/L)
Primary Acute respiratory alkalosis	HCO_3^- decreases 2 mmol/L per 1.3 kPa fall in PaCO_2 below 5 kPa	HCO_3^- decreases 2 mmol/L per 10 mmHg fall in PaCO_2 below 40 mmHg
Chronic respiratory alkalosis	HCO_3^- decreases 5 mmol/L per 1.3 kPa fall in PaCO_2 below 5 kPa	HCO_3^- decreases 5 mmol/L per 10 mmHg fall in PaCO_2 below 40 mmHg
Primary metabolic acidosis	$\text{PaCO}_2 \text{ (kPa)} = 0.2(\text{HCO}_3^-) + 1$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.	$\text{PaCO}_2 = (1.5 \times \text{HCO}_3^-) + 8$ PaCO_2 should be within 5 mmHg of the number denoted after the decimal point in the pH (down to a PaCO_2 10) e.g. pH 7.10 – PaCO_2 should be 10 Alternatively, expected $\text{PaCO}_2 = (\text{HCO}_3^- \times 1.5) + 8$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis.

		If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.
Primary metabolic alkalosis	$\text{PaCO}_2 \text{ (kPa)} = 0.12(\text{HCO}_3) + 1.2$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.	$\text{PaCO}_2 = (0.9 \times \text{HCO}_3) + 9$ PaCO_2 should be within 5mmHg of the number denoted after the decimal point in the pH (up to a PaCO_2 60) e.g. pH 7.6 – PaCO_2 should be 60 Alternatively, expected $\text{PaCO}_2 = (\text{HCO}_3 \times 0.9) + 9$ If the actual PaCO_2 is greater the picture is more complex; e.g. there may be a co-existing respiratory acidosis. If the actual PaCO_2 is lesser the picture is more complex; e.g. there may be a co-existing respiratory alkalosis.

You should try and memorise some of the more common reference ranges for laboratory data, mostly as it saves time when attempting the answer. However, it is recognised that hospitals often have varying reference ranges, based on the equipment calibration, so "normal" values are usually provided in exams. A set of reference ranges is provided for the laboratory values used in the following questions. Click on reference ranges if you need a reminder.

Lab data – Case 1

Question:

A 59 year old lady on the ward has recently been treated for painful active rheumatoid arthritis. While awaiting completion of her discharge planning, a MET call is put out for a witnessed collapse that occurred when she got up to use the bathroom. The first intravenous volume bolus has not improved her blood pressure. What therapy would you consider next?

Urea 11.2mmol/L	Ca 2.37mmol/L
Creatinine 91µmol/L	Mg 0.87mmol/L
Na 127mmol/L	PO4 1.01mmol/L
K 5.9mmol/L	
Cl 96mmol/L	Albumin 36g/L
TCO2 21mmol/L	

BSL 4.1mmol/L

Serum Osm 273mOsm/L

Urine Osm 315mOsm/L

Urine Na 47mmol/L

Urine Cl 21mmol/L

Answer:

Therapy: 100mg Hydrocortisone IV or 4mg Dexamethasone IV and then reinstate a regular oral dose of prednisone. Using dexamethasone will not preclude performing a short synacthen test.

Rationale:

Diagnosis: Addisonism secondary to acute steroid withdrawal

Recent steroid therapy is implied by management of active painful rheumatoid arthritis. The postural hypotensive episode and the blood pressure not responding as expected to a volume challenge is consistent with adrenal insufficiency, as is the hypoosmolar hyponatremia with elevated K, urine Na > 20mmol/L, low blood glucose and normal anion gap metabolic acidosis, using the TCO₂ as a surrogate for HCO₃ .

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 2

Question:

A 22 year old construction worker, who was admitted to the ward two days ago for management of an oblique left tibio-fibular shaft fracture, has been requiring increasing doses of opiate analgesia, despite immobilisation of the injured limb, and today was noted to have a reduced urine output. Outline your initial management.

Urea 24.5 mmol/L	Ca 2.03 mmol/L
Creatinine 266 µmol/L	Mg 0.98 mmol/L
Na 137mmol/L	PO4 1.33 mmol/L
K 6.0 mmol/L	Albumin 39 g/L
Cl 105 mmol/L	
TCO2 20 mmol/L	CK 43,000 U/L
BSL 8.3 mmol/L	Bilirubin 9µmol/L
	AST 246 U/L
	ALT 89 U/L
	GGT 43U/L
	ALP 82 U/L
	LDH 603 U/L

Answer:

Therapy:

- IV hydration with a crystalloid, aiming for a urine output of 1.5 – 2 ml/kg/hr
- Urinary alkalinisation with 0.5mEq/kg NaHCO₃ in 1000mls 0.9% saline, or 1mEq/kg NaHCO₃ in 1000mls 5% dextrose, at 100mls/hr, targeting a urinary pH of greater than 7.0
- The use of diuretics and mannitol to enhance elimination is controversial due to the potential for intravascular volume depletion and an enhanced risk of renal failure.
- Dialysis may be required if acute renal failure ensues, particularly with the hyperkalaemia
- If the limb has been immobilised with a full cast, split the cast to release any pressure due to swelling of the injured limb
- Advocate for theatre to perform a fasciotomy and debridement of any necrotic muscle
- Analgesia

Rationale:

Diagnosis: Rhabdomyolysis due to compartment syndrome

Predisposing injury for compartment syndrome with pain out of proportion to the apparent injury. Acute renal failure, likely due to myoglobinuria, as the raised CK and LDH suggests muscle cell destruction. Myolysis is also suggested by the raised K⁺, PO₄, Mg²⁺ and AST. The low Ca²⁺ is due to sequestration by the damaged tissue, but is rarely clinically significant and can be used as a marker for recovery.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 3

Question:

A 48 year old gentleman is brought to the emergency department via ambulance. He was found in park land, confused. His observations are as follows: HR 107bpm, BP 98/56mmHg, RR 26bpm, SpO₂ 94% RA, Temp 35.6C. What further test would you request?

Urea 11.8mmol/L	Ca 2.05mmol/L
Creatinine 109 µmol/L	Mg 0.72mmol/L
Na 129mmol/L	PO ₄ 1.35mmol/L
K 5.6mmol/L	Albumin 31g/L
Cl 86mmol/L	Uric acid 0.52 mmol/L
TCO ₂ 16mmol/L	
BSL 4.3mmol/L	
Serum Osm 298mOsm/kg	
Urine Osm 387mOsm/kg	
Urine Na 8mmol/L	

Answer:

Test requested: Serum ethanol and methanol level

Rationale:

Diagnosis: Alcohol toxicity

Young to middle aged adult found with an altered level of consciousness in a park usually suggests trauma or toxicology. A hyperosmolar hyponatraemia with a wide osmolar gap and acute renal impairment due to pre-renal deficit is consistent with alcohol toxicity. The raised anion gap metabolic acidosis is due to products of alcohol metabolism and acute renal failure. Hypoglycaemia may be an acute alcohol effect, or, in addition with the low albumin, may reflect malnutrition due to chronic alcoholism.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

-

• Lab data – Case 4

• Question:

- A 53 year old obese gentleman, with a past medical history that includes ischaemic heart disease, and hypertension, presents to the emergency department with confusion and is combative. He is afebrile, with the following observations: HR 113bpm, sinus, BP 108/74mmHg, RR 28bpm, SpO2 96% RA. What is the diagnosis and what therapy would you initiate?

Urea 16.2mmol/L	Serum Osm 352 mOsm/kg
Creatinine 118 $\mu\text{mol/L}$	Urine Osm 476 mOsm/kg
Na 146 mmol/L	Urine Na 32 mmol/L
K 3.8 mmol/L	
Cl 115 mmol/L	Ca 2.56 mmol/L
TCO2 20 mmol/L	Mg 0.76 mmol/L
BSL 36.9 mmol/L	PO4 1.53 mmol/L
	Albumin 48 g/L

-

• Answer:

- Diagnosis: Hyperosmolar hypernatraemic non-ketotic state (HHNS / HONK)
- Therapy:
 - IV rehydration with crystalloid, often requiring an 8 – 10 litre replacement over the next 48 – 72 hours. The onset of HHNS is often subacute, so correction of the deficit should mirror this. Otherwise a rapid fall in the serum Na^+ may result in cerebral oedema.
 - IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts

- K⁺ replacement may be required with the insulin infusion
- Search for and treat the precipitant; commonly sepsis, an acute coronary syndrome or a cerebrovascular event.
- These patients are at higher risk of thromboembolic events, due to the hyperosmolarity, and should receive anticoagulant prophylaxis unless contraindicated.
-
- **Rationale:**
- An obese patient in his 50's with cardiovascular risk factors with a blood glucose that is very high. HHNS hyperglycaemia is often higher than DKA hyperglycaemia. The corrected sodium is high. Don't be put off by the mild metabolic acidosis that is often present. The deranged observations and raised albumin are a reflection of the extreme dehydration, as these patients often have a volume deficit of the order of 8 to 10 litres
- Calc Osm = (2xNa) + Urea + Glucose
- Osmolar Gap = Measured Osm – Calc Osm; normal < 10mOsm/kg
- AG = (Na) - (Cl + HCO₃ or TCO₂). Normal 6-15mmol/L
- Corrected Na = Na + (Glucose/3)
- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 5

Question:

A 34 year old lady, who was admitted with a fever, altered behaviour and a rapid decrease in level of consciousness necessitating invasive airway support, has been noted to have a urine output consistently greater than 150mls/hr. A lumbar puncture is performed and the result, along with her biochemistry is displayed below. What is her diagnosis?

Urea 13.3mmol/L	<u>Lumbar puncture</u>
Creatinine 125µmol/L	Microscopy
Na 152mmol/L	RBC 3 x 10 ⁹ /ml
K 3.8mmol/L	Polymorph 32 x 10 ⁹ /ml
Cl 118mmol/L	Mono 10 x 10 ⁹ /ml
TCO ₂ 23mmol/L	No organisms seen
	Glucose 4.4mmol/L (2.5 – 5.5mmol/L)
Serum Osm 319mOsm/kg	Protein 0.78g/L (0.15 – 0.45g/L)
Urine Osm 236mOsm/kg	

Urine Na 74mmol/L	Cryptococcal Atg negative
Ca 2.41mmol/L	
Mg 0.96mmol/L	
PO4 1.10mmol/L	
Albumin 44g/L	
BSL 6.2mmol/L	
Uric acid 0.61 mmol/L	

Answer:

Diagnosis: Cranial diabetes insipidus secondary to viral encephalitis

Rationale:

Fever with altered behaviour and a rapid decline in conscious level is suggestive of an infective encephalitis, usually viral. The LP biochemistry (raised protein with relatively preserved serum to CSF glucose ratio) and cell count are supportive and a viral PCR should be requested.

A hyperosmolar hypernatraemia with inappropriately hypoosmolar urine is typical of diabetes insipidus. The setting of an intracranial pathology directs you to cranial DI. Additionally, an elevated serum uric acid also supports cranial over nephrogenic DI.

The pre-renal urea to creatinine ratio and raised serum albumin suggest an intravascular volume deficit and is consistent with the main diagnosis

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Lab data – Case 6

Question:

A 36yo lady is admitted to the ward with an exacerbation of her ulcerative colitis. She takes prednisone and azathioprine. She is tachycardic and hypotensive. Her blood results return as follows and the team junior medical officer has requested assistance with managing her SIADH. What would you suggest?

Urea 13.4mmol/L	Serum Osm 268mOsm/kg
Creatinine 101µmol/L	Urine Osm 423mOsm/kg
Na 122mmol/L	Urine Na 4mmol/L
K 3.6mmol/L	Ca 2.15mmol/L
Cl 92mmol/L	Mg 0.77mmol/L
TCO2 19mmol/L	PO4 0.94mmol/L
BSL 7.6mmol/L	Albumin 31g/L

Answer:

Advice:

- Resuscitate her shocked state with crystalloid
- Ongoing fluid replacement over the next 48 hours should correct her hyponatremia gently
- Treat her acute ulcerative colitis exacerbation: 5-aminosalicylate + hydrocortisone or prednisone ± azathioprine

Rationale:

Diagnosis: Extra-renal sodium loss, likely secondary to GI loss due to the patient's exacerbation of ulcerative colitis

Her haemodynamic status suggests a volume deficit, which when combined with her biochemistry, produces a hypovolaemic, hypoosmolar hyponatraemia with avid renal Na retention. This is not consistent with a picture of SIADH. The admission reason suggests that there is significant diarrhoea, which is the most likely source of her extra-renal Na loss. There is a normal AG metabolic acidosis in the presence of hypokalaemia, consistent with GI bicarbonate loss

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L

- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 7

Question:

A 45 year old gentleman is brought to the emergency with increasing dyspnoea. His family have noted that his behaviour recently has been unusual and admit that he is prone to episodic alcohol binges. On examination, he is tachypnoeic and has a distended abdomen.

What is the likely diagnosis and how would you grade it?

Urea 4.1mmol/L	FiO2 28%
Creatinine 72µmol/L	pH 7.46
Na 129mmol/L	PCO2 34mmHg / 4.53 kPa
K 2.9mmol/L	PO2 88mmHg / 11.73kPa
Cl 92mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 6.4mmol/L	Hb 93g/dL
	MCV 107fl (normal 78-101 fl)
Ca 1.85mmol/L	MCH 27pg (normal 25-35 pg/cell)
Mg 0.68mmol/L	WBC 8.1x10 ⁹ /L
PO4 0.75mmol/L	PLT 105x10 ⁹ /L
Albumin 26g/L	
	aPTT 39s
Bilirubin 6µmol/L	PT 22s
AST 33U/L	INR1.5
ALT 42U/L	

GGT 57U/L

ALP 94U/L

Serum Osm 270mOsm/kg

Urine Osm 224mOsm/kg

Urine Na 7mmol/L

How would you interpret the results of the abdominal paracentesis and how do they affect your choice of therapy?

Ascitic fluid

Glucose 2.3 mmol/L

Albumin 54 g/L

pH 7.32

WBC 577 $\times 10^9$ /ml

Polymorphs 444 $\times 10^9$ /ml

RBC 89 $\times 10^9$ /ml

Gram stain: Polymorphs ++

Culture: Pure growth of Enterobacter species

Answer:

Diagnosis: Hepatic encephalopathy due to spontaneous bacterial peritonitis on a background of alcoholic cirrhosis, Childs-Pugh Grade B. The identification of an enterobacter species, an ESCAPM organism, narrows the available choice of antibiotics to gentamicin or a carbapenem.

Rationale:

A history of alcoholism. The distended abdomen is probably ascites. Hypoosmolar hyponatraemia with a low urea (which suggests he is not hypovolaemic nor in renal failure and has a decreased liver synthetic function), plus low K

(due to the impaired aldosterone metabolism), low albumen and prolonged PT and INR (due to impaired liver synthetic function). The serum and urine osmolarities also suggest he is not hypovolaemic and would not be consistent with an SIADH, thus favouring a hypervolaemic hypoosmolar hyponatraemia, such as cirrhosis. The respiratory alkalosis and mild A-a gradient would be consistent with limited diaphragmatic movement and basal atelectasis due to ascites or a metabolic encephalopathy. The LFTs need not be grossly disturbed, especially if there is little functional hepatic tissue remaining.

ESCAPM agents are identified by the presence of the Amp-C gene, which codes for an inducible β -lactamase that results in apparent in vitro sensitivity, but inevitable in vivo β -lactam resistance.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal $6-15 \text{ mmol/L}$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

Child's-Pugh grading			
Score	1	2	3
Bilirubin ($\mu\text{mol/L}$)	<34	34-51	>51
Albumen (g/L)	>35	28-35	<28
PT (+ secs)	1-3	3-6	>6
Ascites	0	Grade I	Grade II
Encephalopathy	0	1-2	3-4
(West-Haven grade)			

5-6 = Child-Pugh A ® Too early for liver transplant referral

7-9 = Child-Pugh B ® Discuss with transplant team

10-15 = Child-Pugh C ® Refer to transplant team for assessment

Lab data – Case 8

Question:

A 78 year old gentleman is on SIMV with PEEP = 10 and Pmean = 18mmHg, for lobar pneumonia. He is on $0.06 \mu\text{g/kg/min}$ of noradrenalin to maintain a MAP of 65mmHg. His urine output averages 40ml/hr. The nurse is concerned about the hyponatraemia. What is causing it?

Urea 7.6 mmol/L	Bilirubin $9 \mu\text{mol/L}$
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Creatinine 71 μ mol/L	AST 39 U/L
Na 123mmol/L	ALT 36 U/L
K 4.2mmol/L	GGT 62 U/L
Cl 89mmol/L	ALP 101 U/L
TCO2 23mmol/L	
BSL 7.3mmol/L	Serum Osm 275mOsm/kg
Ca 2.26mmol/L	Urine Osm 461mOsm/kg
Mg 0.88mmol/L	Urine Na 39mmol/L
PO4 1.13mmol/L	
Albumin 34g/L	

Answer:

Diagnosis: SIADH

Rationale:

Hypoosmolar hyponatraemia with an inappropriately high urine osmolarity for the low serum osmolarity and a urine Na > 20mmol/L is almost enough by itself in an exam. A normal urea and creatinine and reasonable urine output suggest he is euvolaemic. The otherwise normal EUC, BSL, LFTs and Ca²⁺ reduce the likelihood of a renal, liver or adrenal cause, as required for the diagnosis of SIADH. The noradrenaline dose is minimal. The pneumonia is the likely precipitant of the SIADH.

If there were clinical clues that the patient was hypovolaemic (e.g. dry mucous membranes, lack of tissue oedema, lack of pulmonary oedema, tachycardia, hypotension) then consider a salt wasting syndrome, cerebral or renal, which may be quite similar biochemically, but are managed very differently (fluid restriction for SIADH, fluid replacement for salt wasting syndromes)

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L

Lab data – Case 9

Question:

A 53 year old lady has been in your ICU for 13 days following resolution of community acquired pneumonia. Having undergone aggressive early goal directed therapy by the unit registrar for her initial septic shock, she has been slow to wean from invasive mechanical ventilation, due to a persistent FiO₂ and PEEP requirement, despite the resolution of her inflammatory markers several days earlier. Her observations are: HR 92bpm sinus, BP 106/73 (no vasopressor), RR 28bpm, SpO₂ 95%, Temp 36.7°C, Urine output 60 – 120ml/hr. The nurse is concerned about the ongoing need for potassium replacement. What is the likely cause?

Urea 12.7mmol/L	pH 7.47
Creatinine 99µmol/L	PCO ₂ 46mmHg / 6.13 kPa
Na 124mmol/L	PO ₂ 92mmHg / 12.27 kPa
K 3.1mmol/L	HCO ₃ 29mmol/L
Cl 88mmol/L	SBE +3
TCO ₂ 32mmol/L	
BSL 8.3mmol/L	
Serum Osm 273mOsm/kg	
Urine Osm 325mOsm/kg	
Urine Na 34mmol/L	

Answer:

Diagnosis: Potassium-losing diuretic (e.g. frusemide, which is commonly used in ICUs)

Rationale:

Hypoosmolar hyponatraemia with hypovolaemia, suggested by the upper limit of normal HR and lower limit of normal BP in the presence of a volume contraction hypokalaemic metabolic alkalosis. The urine Na > 20mmol/L suggests renal sodium loss. The differential includes a loop diuretic or a salt wasting syndrome. The eager initial volume

resuscitation of her septic shock (EGDT), along with any sepsis related non-cardiogenic pulmonary oedema, is the likely cause for the slow ventilator wean and is being treated with a loop diuretic, resulting in the above biochemistry. It is also possible that the metabolic alkalosis that has been induced by the loop diuretic is also hindering the weaning process and it could be ameliorated by some acetazolamide.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L

Lab data – Case 10

Question:

A 25 year old gentleman is admitted to your ICU heavily sedated, intubated and ventilated following a fall from construction scaffolding. He sustained rib fractures and significant head injury. He has just returned from the operating theatre, where a decompressive craniectomy was performed. What is your explanation for his initial blood picture?

Urea 7.3mmol/L	Serum Osm 334mOsm/kg
Creatinine 87µmol/L	Urine Osm 417mOsm/kg
Na 151mmol/L	Urine Na 32mmol/L
K 2.6mmol/L	
Cl 116mmol/L	Ca 2.25mmol/L
TCO2 26mmol/L	Mg 0.87mmol/L
	PO4 0.96mmol/L
BSL 8.1mmol/L	Albumin 32g/L

Answer:

Diagnosis: Recent mannitol therapy

Rationale:

A traumatic brain injury with management suggesting there have been difficulties maintaining an appropriate ICP. Hyperosmolar hyponatraemia with a widened osmolar gap $> 10 \text{mOsm/L}$, consistent with recent mannitol therapy. The hypokalaemia suggests that the sedating agent may be thiopentone

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/L}$

Lab data – Case 11

Question:

A 59 year old lady is admitted to your ICU, having had several seizures at home. She is markedly icteric and has been intubated in the emergency department. Outline your management strategy for the first 24 hours of her admission.

Urea 18.7mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.27
Na 127mmol/L	PCO2 24mmHg / 3.20 kPa
K 3.2mmol/L	PO2 116mmHg / 15.47 kPa
Cl 87mmol/L	HCO ₃ 16mmol/L
TCO2 21mmol/L	SBE -9
BSL 2.1mmol/L	Hb 86g/dL
Ca 1.99mmol/L	MCV 111fl (normal = 78-101 fl)
Mg 0.68mmol/L	MCH 102pg (normal = 25-35 pg/cell)
PO4 0.62mmol/L	WBC $12.1 \times 10^9/\text{L}$
Albumin 28g/L	PLT $117 \times 10^9/\text{L}$
Bilirubin 134µmol/L	aPTT 41s
AST 928U/L	PT 25s
ALT 342U/L	INR 1.7

GGT 257U/L

ALP 184U/L

Serum Osm 279mOsm/kg

Urine Osm 194mOsm/kg

Urine Na 13mmol/L

Answer:

Management:

- Correct the hypoglycaemia with 50% Dextrose initially and then an ongoing 5 – 10% dextrose infusion until stable normoglycaemia
- Correct any hypovolaemia or dehydration
- Advocate for an urgent upper GI endoscopy to identify bleeding ulcer disease or varices
- Start IV octreotide 50µcg bolus and then 50µcg/hr infusion
- Start IV pantoprazole 80mg bolus and then 10mg/hr infusion
- Give IV vitamin K 5mg. Give FFP also if there is evidence of active bleeding.
- Start lactulose – PR prior to the endoscopy and via the nasogastric tube afterwards.
- Exclude sepsis, including spontaneous bacterial peritonitis
- Minimise opiate and benzodiazepine use during her period of intubation in order to avoid a prolonged sedation wean.

Rationale:

Diagnosis: Alcohol-induced acute on chronic liver failure with encephalopathy, hypoglycaemia and a likely upper GI bleed

Moderate transaminitis with an AST : ALT ratio > 2, suggests an alcoholic hepatitis. The history, level of transaminitis and hyperbilirubinaemia suggest an acute process. The hypoglycaemia, hypoalbuminaemia and prolonged PT / INR suggest diminished hepatic reserve and synthetic function and an underlying chronic dysfunction, such as cirrhosis. In addition, the low creatinine relative to the urea suggests a low muscle mass and possible malnutrition. The anaemia may be acute and, with the elevated urea out of proportion to the creatinine, may be the result of an upper GI bleed, either ulcerative or variceal. It may also reflect the alcoholic background – low Hb with raised MCV. The raised anion gap metabolic acidosis could be the result of a lactic acidosis from impaired liver function, an acute pancreatitis, an alcoholic or starvation ketosis or alcohol toxicity (less likely with the normal osmolar gap).

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L

- Corrected Ca = Ca + 0.02(40 – albumin)

Lab data – Case 12

Question:

A 37 year old lady is admitted to the maternity ward at 34 weeks gestation (G2P1) with upper abdominal discomfort and a sensation that her shoes and rings are too tight. She has not attended any ante-natal care. On examination she has a fundal height of 35cm and six beats of clonus. Her urine appears dark. Her observations are as follows, HR 102bpm sinus, BP 133/87mmHg, RR 18bpm, SpO2 100% on nasal prongs at 4L/min, Temp 37.1°C. What management conflicts do you face for this patient?

Urea 5.9mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.43
Na 132mmol/L	PCO2 32mmHg / 4.27 kPa
K 3.4mmol/L	PO2 121mmHg / 16.13 kPa
Cl 95mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 5.1mmol/L	Hb 94g/dL
Ca 2.14mmol/L	MCV 108fl (normal = 78-101 fl)
Mg 0.72mmol/L	MCH 37pg (normal = 25-35 pg/cell)
PO4 0.92mmol/L	WBC 12.3x10 ⁹ /L
Albumin 33g/L	PLT 125x10 ⁹ /L
Bilirubin 56µmol/L	aPTT 34s
AST 137U/L	PT 21s
ALT 144UI/L	INR1.4

GGT 108U/L

ALP 139U/L

Serum Osm 273mOsm/kg

Urine Osm 182mOsm/kg

Urine Na 9mmol/L

Urine protein + + +

Answer:

Conflicts:

1. The patient is demonstrating features of evolving pre-eclampsia and HELLP syndrome. However, at 34 weeks gestation, foetal lung maturity is underdeveloped and a dose of dexamethasone 24 hours prior to delivery is desirable. Providing this period without excessive risk to the mother's health is a delicate timing issue.
2. Operative intervention in the setting of an uncontrolled coagulopathy presents an increased bleeding risk. The blood products used to correct the coagulopathy have a higher than usual risk of precipitating pulmonary oedema in this population of patients.
3. Once in the ICU, there is often a conflict of interest between supporting renal perfusion with fluids and precipitating pulmonary oedema. Both are transient, but most centres give preference to preventing pulmonary oedema and accepting a period of oliguria and deranged renal biochemistry.

Rationale:

Diagnosis: Preeclampsia / HELLP syndrome

Third trimester hypertension. The tachycardia and tachypnoea may simply reflect her third trimester status. More than 3 – 4 beats of clonus indicates hypertonicity and would be suggestive of preeclampsia in combination with her elevated blood pressure, peripheral oedema (tight rings and shoes) and proteinuria (the urine protein:creatinine ration suggests a proteinuria > 200mg/24hrs). The largely hepatitic LFTs suggest that there is more than just pre-eclampsia present and, in combination with the low platelets, indicates the presence of HELLP syndrome. Therefore, the upper abdominal discomfort may represent hepatic congestion, a subcapsular haematoma or a hepatic infarct. The raised bilirubin may be due to one or both of hepatitis or haemolysis. Remember that in the third trimester a mild compensated respiratory alkalosis is normal.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal $< 10 \text{ mOsm/kg}$
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$
- Normal urine protein to creatinine ration is < 0.2

Lab data – Case 13

Question:

You are called to see a 29 year old woman, 33 weeks pregnant with a respiratory rate of 55/min. Her pregnancy has been complicated by persistent gestational nausea. She is otherwise healthy. The following pathology is available.

a) What is the likely diagnosis?

Day 1	Day 2
Urea $< 0.7 \text{ mmol/L}$	Urea $< 0.7 \text{ mmol/L}$
Creatinine $49 \text{ } \mu\text{mol/L}$	Creatinine $51 \text{ } \mu\text{mol/L}$
Na 135 mmol/L	Na 136 mmol/L
K 3.6 mmol/L	K 4.0 mmol/L
Cl 109 mmol/L	Cl 114 mmol/L
TCO ₂ 9 mmol/L	TCO ₂ 7 mmol/L
Urate 0.6 mmol/L	Osm 290 mOsm/kg
Hb 12.3 g/dL	Ca 2.35 mmol/L
WCC $15.9 \times 10^9/\text{L}$	Mg 0.79 mmol/L
PLT $256 \times 10^9/\text{L}$	PO ₄ 0.98 mmol/L
	Albumin 32 g/L
	Prot 73 g/L

	Bilirubin 14 µmol/L
	ALT 29 U/L
	AST 96 U/L
	GGT 34 U/L
	ALP 217 U/L
	Glucose 4.3 mmol/L
	pH 7.19
	PaCO ₂ 17 mmHg / 2.27 kPa
	PaO ₂ 124 mmHg / 16.53 kPa
	HCO ₃ 7 mmol
	SBE -19 mmol/L
	Lactate 0.69 mmol/L
	Hb 12.3 g/dL
	WCC 17.3 x10 ⁹ /L
	Plt 339 x10 ⁹ /L

b) She was subsequently treated appropriately. The following day, her morning bloods return What complication has occurred?.

Na 135 mmol/L	Ca 2.00 mmol/L
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K 3.5 mmol/L	Mg 0.85 mmol/L
Cl 110 mmol/L	PO4 0.36 mmol/L
TCO2 17 mmol/L	Albumin 21 g/L

Answer:

a) Starvation ketosis in pregnancy.

b) Refeeding syndrome.

Rationale:

This third trimester lady should have a mild compensated respiratory alkalosis as part of normal physiology. Instead she has a profound raised AG metabolic acidosis, in the absence of lactate, drugs or renal failure. That leaves ketosis. She is not diabetic and the blood glucose does not suggest a DKA. In fact the glucose is lower than expected, as is the albumen. Assuming she is not alcohol toxic, this leaves only starvation ketosis, which may be the result of her persistent gestational nausea. The raised WBC may be normal for gestation or a stress response to her illness

The low phosphate on day three suggests the appropriate therapy that she received included a carbohydrate load, resulting in refeeding syndrome.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

• Expected PaCO_2 for metabolic acidosis: mmHg = $(\text{HCO}_3 \times 1.5) + 8$; kPa = $0.2(\text{HCO}_3) + 1$

Lab data – Case 14

Question:

A 19 year old gentleman presents with abdominal pain and vomiting. He looks dehydrated and pale. He has no known medical history. His observations are as follows: HR 118bpm sinus, BP 104/62mmHg, RR 32bpm, SpO2 100%, Temp 37.8°C, Urine output 100 – 140ml/hr. How will you manage him initially?

Urea 17.8mmol/L	pH 7.13
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Creatinine 103µmol/L	PaCO ₂ 15 mmHg / 1.99 kPa
Na 130 mmol/L	PaO ₂ 124 mmHg / 16.53 kPa
K 3.0 mmol/L	HCO ₃ 7 mmol
Cl 87 mmol/L	SBE -21 mmol/L
TCO ₂ 11 mmol/l	Lactate 4.7 mmol/L
Osm 305mOsm/kg	Hb 13.1 g/dL
Ca 2.43 mmol/L	WCC 16.3 x10 ⁹ /L
Mg 0.54 mmol/L	Plt 532 x10 ⁹ /L
PO ₄ 1.06 mmol/L	
Albumin 43 g/L	
Bilirubin 11 µmol/L	
ALT 27 U/L	
AST 35 U/L	
GGT 28 U/L	
ALP 100U/L	
Glucose 24 mmol/L	
Lipase 68U/L	

Answer:

Management:

- IV rehydration with crystalloid, often requiring a 4 – 6 litre replacement over the next 24 – 48 hours, depending upon the rapidity of the onset of this illness.
- IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts
- K+ replacement will be required with the insulin infusion, given the total body K+ depletion evident
- Search for and treat the precipitant; commonly sepsis, trauma or drugs in a young person.

Rationale:

Diagnosis: DKA, as a first presentation of type I diabetes mellitus.

Moderate hyperglycaemia with a raised AG metabolic acidosis. The raised lactate is not enough to account for all of the AG and the deficit is made up by ketones. The patient shows evidence of hypovolaemia and dehydration clinically, yet is polyuric. The low potassium is a concern, given the level of acidosis, and suggests significant depletion of total body potassium reserves. This suggests that the patient has been unwell for some time and will need careful electrolyte management over the next 48 to 72 hours, including replacement of the magnesium.

The Hb may reflect dehydration. The WBC is non-specific and may be associated with infection as a precipitant of the DKA, or may be a stress response. The thrombocytosis is associated with acute inflammation and dehydration

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

• Expected PaCO_2 for metabolic acidosis: $\text{mmHg} = (\text{HCO}_3 \times 1.5) + 8$; $\text{kPa} = 0.2(\text{HCO}_3) + 1$

Lab data – Case 15

Question:

Your registrar has just reviewed an oncology patient who recently started chemotherapy for a large, abdominal, high grade, non-Hodgkin's lymphoma. The patient has been oliguric for several hours. What is the diagnosis?

Urea 24mmol/L	Glucose 24 mmol/L
Creatinine 239µmol/L	Lipase 89U/L
Na 150 mmol/L	Uric acid 0.49 mmol/L
K 6.4 mmol/L	
Cl 116 mmol/L	pH 7.25

TCO2 17 mmol/l	PaCO2 27 mmHg / 3.60 kPa
	PaO2 124 mmHg 16.53 kPa
Osm 327mOsm/kg	HCO ₃ 12 mmol
	SBE –15 mmol/L
Ca 1.63 mmol/L	Lactate 2.8 mmol/L
Mg 0.99 mmol/L	
PO4 1.45 mmol/L	Hb 10.1 g/dL
Albumin 43 g/L	WCC 18.6 x10 ⁹ /L
	Plt 156 x10 ⁹ /L
Bilirubin 16 µmol/L	
ALT 32 U/L	
AST 34 U/L	
GGT 43 U/L	
ALP 107U/L	
LDH 514 U/L	

Answer:

Diagnosis: Tumour lysis syndrome

Rationale:

High grade lymphomas and leukaemias with high WBC counts are at increased risk of tumour lysis syndrome, as is the first dose of chemotherapy for a large tumour load. Raised K⁺, PO4, LDH and uric acid support the diagnosis. The hyperkalaemia is in excess of that expected for the acidosis – K⁺ rises by 0.5 for every fall in pH of 0.1. The low Ca²⁺ despite a metabolic acidosis has a limited differential, including tumour lysis syndrome and rhabdomyolysis. The

widened AG is due to the release of intracellular acids from lysed cells and contributes to the hyperkalaemia and hyperuricaemia

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10 mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or TCO}_2)$. Normal 6-15 mmol/L
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumin})$

• Expected PaCO_2 for metabolic acidosis: mmHg = $(\text{HCO}_3 \times 1.5) + 8$; kPa = $0.2(\text{HCO}_3) + 1$

Lab data – Case 16

Question:

Your registrar is concerned about a patient in the unit who is proving difficult to wean from ventilatory support. The patient has multiple small bowel fistulae following an open necrosectomy and several revisions for significant necrotising pancreatitis and the surgeons have requested that TPN be continued for 2 – 3 more weeks. The pancreatitis has been settled for some time and all inflammatory markers have returned to normal. Drain outputs are negligible. The patient has a tracheostomy and remains on pressure support ventilation. There are no vasopressors required and the urine output is satisfactory. The patient is receiving an insulin infusion at 12u/hr. The patient is on no antibiotic and has a clear CXR and clear urine microscopy. The observations are as follows: RR 32bpm, SpO₂ 98% (FiO₂ 0.3), HR 110bpm sinus, BP 128/76mmHg, Temp 38.3°C. You are shown the most recent blood results. What is your response?

Urea 11.3mmol/L	Glucose 15 mmol/L
Creatinine 99µmol/L	Lipase 89U/L
Na 147 mmol/L	Uric acid 0.45mmol/L
K 5.5 mmol/L	
Cl 112 mmol/L	pH 7.32
TCO ₂ 29 mmol/l	PaCO ₂ 48 mmHg / 6.39 kPa
	PaO ₂ 154 mmHg / 20.53 kPa
Osm 332.3mOsm/kg	HCO ₃ 28 mmol
	SBE +3 mmol/L
Ca 2.39mmol/L	Lactate 1.1 mmol/L
Mg 1.19 mmol/L	

PO4 1.22 mmol/L	Hb 10.1 g/dL
Albumin 28 g/L	WCC $14.3 \times 10^9/L$
	Plt $259 \times 10^9/L$
Bilirubin 18 $\mu\text{mol/L}$	
ALT 62 U/L	
AST 58U/L	
GGT 121 U/L	
ALP 126 U/L	
Triglycerides 3.01 mmol/L	
Total cholesterol 5.7 mmol/L	

Answer:

Diagnosis: Overfeeding syndrome

Response: Decrease the TPN rate and adjust the contents and proportions to meet the patient's nutritional needs appropriately.

Rationale:

The patient is in the weaning phase and the acute pathology has settled. Therefore complications of therapy must be considered when evaluating new problems. Despite a lack of active pancreatitis markers and no apparent infection source, the patient remains tachypnoeic, tachycardic and hyperthermic. This is due to the increased metabolic state from the excess nutritional supply. The excess nutrition results in hyperglycaemia, (despite being chased by a higher than usual insulin infusion rate in this patient), hyperlipidaemia, mildly deranged LFTs (hepatic steatosis from the hyperlipidaemia) and electrolyte disturbances, along with increased CO₂ production. Patients with overfeeding syndrome may also display delirium, peripheral oedema and excess weight gain.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Osmolar Gap} = \text{Measured Osm} - \text{Calc Osm}$; normal < 10mOsm/kg
- $\text{AG} = (\text{Na}) - (\text{Cl} + \text{HCO}_3 \text{ or } \text{TCO}_2)$. Normal 6-15mmol/L
- $\text{Corrected Na}^+ = \text{Na} + (\text{Glucose}/3)$

- Corrected Ca = Ca + 0.02(40 – albumin)
- Expected HCO₃ for respiratory acidosis: Acute - HCO₃ increases 1mmol/L per 10mmHg rise in p_aCO₂ above 40mmHg (up to 30mmol/L) ; HCO₃ increase 1mmol/L per 1.3kPa rise in p_aCO₂ above 5kPa (up to 30mmol/L)

•Expected HCO₃ for respiratory acidosis: Chronic - HCO₃ increases 4mmol/L per 10mmHg rise in p_aCO₂ above 40mmHg (up to 36mmol/L); HCO₃ increases 4mmol/L per 1.3 rise in p_aCO₂ above 5kPa (up to 36mmol/L)

Lab data – Case 17

Question:

A 56 year old gentleman is transferred from a regional hospital following a difficult intubation for repeated seizures. The intubation was made difficult by tongue swelling that occurred when the patient bit his own tongue during one of his seizures. His initial blood results return as follow:

Na 142mmol/L	Hb 6.7 g/dL
K 3.8 mmol/L	Retics 503 x 10 ⁹ /L
Cl 106 mmol/L	WBC 9.2 x 10 ⁹ /L
HCO ₃ 28mmol/L	Neut 6.5 x 10 ⁹ /L
Urea 10.6 mmol/L	Lymph 2.3 x 10 ⁹ /L
Creatinine 117 µmol/L	MCV 103fl (normal 78-101 fl)
	MCH 35 (normal 25-35 pg/cell)
Uric acid 0.35 mmol/L	MCHC 348 (normal 31 – 36 Hb/cell)
Glucose 11.7 mmol/L	RDW 28.9
	PLT 39 x 10 ⁹ /L
Bili 36 µmol/L	
ALT 13 U/L	Comment: Neutrophils show slight left shift.
AST 29 U/L	Marked polychromasia. Many fragmented red cells.
ALP 75 U/L	
GGT 17 U/L	PT 15.0 s (11.0 – 15.0s)
Alb 31 g/L	INR 1.22

Prot 57 g/L	aPTT 25.8 s (24.0 – 33.0s)
LDH 1,352 U/L	Fibrinogen 3.02 g/L (2.00 – 4.00g/L)
	D-dimer 10.86 µg/ml (<1.00)
Ca 2.03 mmol/L	
PO4 0.69 mmol/L	
Mg 0.89 mmol/L	

a) What diagnosis would you consider?

b) What specific therapy would you consider?

Answer:

Diagnosis: Thrombotic thrombocytopenic purpura

Therapy:

- Plasmapheresis – recommended first line therapy for TTP
- Immunoglobulin
- Methylprednisone

Rationale:

Seizures (neurology) + renal failure + thrombocytopenia + haemolytic anaemia (low Hb + raised reticulocytes + raised LDH + fragmented red cells on the blood film). A history of a febrile illness would complete the TTP pentad. The raised D-dimer is related to the microvascular thrombosis that is part of the pathology

Lab data – Case 18

Question:

A 37 year old lady is in the emergency department with abdominal pain. The emergency registrar is concerned enough to request you to review the blood results and tells you that she is a mildly obese woman, with swelling in the region of both angles of her jaw. Her abdomen is soft with no consistent regional tenderness. She has no known past

medical history and is not on any regular medications. Her heart rate, blood pressure, respiratory rate and oxygen saturation are normal.

Na 120 mmol/L	pH 7.51
K 2.0 mmol/L	PaCO ₂ 49 mmHg / 6.53 kPa
Cl 64 mmol/L	PaO ₂ 103 mmHg / 13.73 kPa
HCO ₃ 48 mmol/L	HCO ₃ 45mmol/L
Urea 4.2 mmol/L	SBE +13
Creatinine 67 µmol/L	SaO ₂ 99%
Glucose 5.5 mmol/L	
Bili 11 µmol/L	
ALT 20 U/L	
AST 34 U/L	
ALP 70 U/L	
GGT 19 U/L	
Alb 38 g/L	
Prot 63 g/L	
Ca 2.24 mmol/L	
PO ₄ 0.98 mmol/L	
Mg 0.85 mmol/L	

a) What diagnosis would you consider?

b) What additional features would you examine for to support your diagnosis?

Answer:

a) Diagnosis: Bulimia nervosa

b) Supportive features: Eroded fingernails, from repeated self-induced vomiting, erosion of dental enamel, especially of the incisors.

Rationale:

Mildly obese female with bilateral parotid swelling, due to repeated self-induced vomiting, and a non-specific abdominal complaint + a metabolic alkalosis which is hypokalaemic and hypochloraemic, which suggests H⁺ ion loss + a hyposmolar hyponatremia due to extra renal sodium loss.

- $\text{Calc Osm} = (2 \times \text{Na}) + \text{Urea} + \text{Glucose}$
- $\text{Corrected Ca} = \text{Ca} + 0.02(40 - \text{albumen})$

• Expected PaCO₂ for metabolic alkalosis: mmHg = (HCO₃ x 0.9) + 9; kPa = 0.12(HCO₃) + 1.2

Lab data – Case 19

Question:

A 31 year old lady is admitted to the ICU from theatres following a dilation and curettage for a foetal death in utero at 18 weeks gestation. She had become febrile and hypotensive over the past 24 hours, precipitating the operation. Her procedure was complicated by heavy blood loss and she received 7 units of packed red blood cells and 4 units of fresh frozen plasma. Her admission haematology is as follows:

Hb 7.6 g/dL	PT 31.9 s (11.0 – 15.0s)
WBC 20.9 x 10 ⁹ /L	INR 3.10
Neut 18.7 x 10 ⁹ /L	aPTT 85.9 s (24.0 – 33.0s)
Lymph 1.2 x 10 ⁹ /L	Fibrinogen 1.22 g/L (2.00 – 4.00g/L)
MCV 99fl (78-101 fl)	Thrombin time 22.1s (15.0 – 19.0s)
MCH 34 (25-35 pg/cell)	D-dimer 8.93 µg/ml (<1.00)

MCHC 338 (31 – 36 Hb/cell)	
RDW 15.3	
PLT $128 \times 10^9/L$	

What haematological condition would you suspect?

Answer:

Diagnosis: Disseminated intravascular coagulopathy (DIC)

Rationale:

Raised aPTT, PT, Thrombin time and D-dimer with a low fibrinogen + thrombocytopenia. The likely precipitants include a septic (febrile, hypotensive and leucocytosis) abortion and the massive blood transfusion, which has not followed a 1:1 Packed RBCs to FFP ratio, with no platelets given.

Lab data – Case 20

Question:

A 72 year old gentleman has been intubated in the emergency department for increasing work of breathing and a decline in his level of consciousness during the management of his suspected community acquired pneumonia. The nurse looking after him shows you his first blood gas following his transfer to the ICU. What measures would you take?

FiO ₂ 0.5	Hb 9.1g/dL
pH 7.49	Na 137 mmol/L
PaCO ₂ 26 mmHg	K 3.7mmol/L
PaO ₂ 101 mmHg	iCa 1.13 mmol/L
HCO ₃ 20 mmol/L	iCa (pH 7.40) 1.18mmol/L

SBE -2.8	Glucose 6.3 mmol/L
SaO2 98%	Lactate 1.1 mmol/L

Answer:

Measures to take: Check the ventilator minute ventilation, ventilator frequency and tidal volume. Usually a decrease of the frequency is all that is required. The tidal volume may need to be reduced if inappropriately high. Check that the patient is not in pain and has an appropriate level of sedation to assist tolerance of invasive ventilation. Exclude alternative pathologies, such as meningitis, encephalitis, cerebral oedema or drug toxicities (e.g. salicylate, theophylline).

Rationale:

Diagnosis: Respiratory alkalosis due to overventilation.

Raised pH with a low PaCO₂ and appropriate compensatory fall in the HCO₃ in a mechanically ventilated patient. There is also a raised Aa gradient, though this is unlikely to be driving a tachypnoea given the adequate PaO₂. There is no evidence of a co-existing metabolic acidosis to drive an increased respiratory drive.

- Expected HCO₃ for respiratory alkalosis: Acute - HCO₃ decreases 2mmol/L per 10mmHg fall in paCO₂ below 40mmHg; HCO₃ decreases 2mmol/L per 1.3 fall in paCO₂ below 5kPa
- Expected HCO₃ for respiratory alkalosis: Chronic - HCO₃ decreases 5mmol/L per 10mmHg fall in paCO₂ below 40mmHg; HCO₃ decreases 5mmol/L per 1.3kPa fall in paCO₂ below 5kPa

Lab data – Case 21

Question:

A 48 year old lady is brought to the emergency department confused and febrile, with a heart rate of 140bpm and a blood pressure of 220/97mmHg. She appears mildly cachectic. Her blood tests are presented below.

Na 144 mmol/L	Hb 11.6 g/dL
K 4.4 mmol/L	WBC 15.7 x 10 ⁹ /L
Cl 106 mmol/L	Neut 14.7 x 10 ⁹ /L

HCO ₃ 23 mmol/L	Lymph 0.5 x 10 ⁹ /L
Urea 18.3 mmol/L	MCV 84fl (normal 78-101 fl)
Creatinine 253 µmol/L	MCH 30 (normal 25-35 pg/cell)
	MCHC 34.6 (normal 31 – 36 Hb/cell)
Glucose 11.5 mmol/L	RDW 13.4
CK 562 U/L	PLT 86 x 10 ⁹ /L
Ca 2.11 mmol/L	
PO4 1.38 mmol/L	
Mg 1.10 mmol/L	
Free T4 47.8 pmol/L (10.5 – 21.2pmol/L)	
TSH 0.050 mIU/L (0.35 – 0.36mIU/L)	
Free T3 6.6 pmol/L (2.5 – 7.3pmol/L)	

What specific therapy would you suggest?

Answer:

Therapy, in order of administration:

- Decrease the systemic sensitivity of catecholamine receptors and the peripheral conversion of T4 to T3 using non-selective β-blocker: Propranolol 0.5 – 1mg IV q5min until HR less than 100bpm to maximum 10mg, then enteral propranolol 60 – 120mg q4hr until the crisis abates. Cardioselective β-blockers can be used, but are less effective. Guanethedine or reserpine are used in patients with reactive airways disease or other contraindications to β-blockers.
- Reduce thyroid hormone synthesis: Enteral propylthiouracil 1000mg loading dose, then 200 – 400 mg q4hr. Carbimazole has also been used.
- Reduce the release of preformed thyroid hormone: Lugol's iodine 8 - 10 drops q6hr enterally. Alternatively, iodinated contrast agent can be used if Lugol's iodine is not available.
- Steroids: Hydrocortisone 300 mg loading followed by 100 mg tds, as there is often a relative hypoadrenalism. It also alters the peripheral conversion of existing thyroid hormones. .

- Treat the precipitant – usually sepsis.
- Supportive therapy – fluid balance, nutritional support, avoid salicylates and frusemide which can release bound thyroid hormone, active cooling of hyperpyrexia, thiamine and sedation if agitated.

Rationale:

Diagnosis: Hyperthyroid crisis

High T4 with suppressed TSH is consistent with primary hyperthyroidism (Grave's disease, toxic multinodular goitre, acute Reidel's thyroiditis, amiodarone-induced thyroiditis). Also consistent with a thyrotoxic crisis is her clinical presentation with fever, confusion and increased heart rate and BP. Associated laboratory abnormalities include hyperglycaemia (including non-diabetics), raised WBC, raised Ca^{2+} and low K^+ and Mg^{2+}

Lab data – Case 22

Question:

A 19 year old lady has been brought to the emergency department by her friends, in a state of inebriation. She is tearful and incoherent, requiring a small dose of midazolam to calm her. Her friends state that she recently broke up with her boyfriend. What therapy would you consider based on her blood results?

Na 143 mmol/L	Hb 12.4g/dL
K 4.7 mmol/L	WBC $13.6 \times 10^9/\text{L}$
Cl 99 mmol/L	Neut $11.7 \times 10^9/\text{L}$
HCO_3^- 19 mmol/L	Lymph $1.2 \times 10^9/\text{L}$
Urea 5.9 mmol/L	MCV 90fl (normal 78-101 fl)
Creatinine 182 $\mu\text{mol/L}$	MCH 31 (normal 25-35 pg/cell)
	MCHC 33.8 (normal 31 – 36 Hb/cell)
Glucose 5.9 mmol/L	RDW 10.9
	PLT $201 \times 10^9/\text{L}$
Bili 113 $\mu\text{mol/L}$	
ALT 2029 U/L	PT 34.3 s (11.0 – 15.0s)
AST 3006 U/L	INR 3.24

ALP 39 U/L	aPTT 41.7 s (24.0 – 33.0s)
GGT 38 U/L	Fibrinogen 2.32 g/L (2.00 – 4.00g/L)
Alb 33 g/L	Thrombin time 17.6s (15.0 – 19.0s)
Prot 52 g/L	D-dimer >20.0 µg/ml (<1.00)
Ca 1.88 mmol/L	FiO2 0.3
PO4 1.84 mmol/L	pH 7.23
Mg 1.12 mmol/L	PaCO2 46 mmHg / 6.13 kPa
	PaO2 89 mmHg / 11.87 kPa
	HCO ₃ 19 mmol/L
	SBE -7.6
	SaO2 97%

Answer:

Therapy:

- Consider ventilatory support for the respiratory acidosis, as her impaired liver may not metabolise the "small dose of midazolam" effectively.
- Start N-acetylcysteine infusion.
- Vitamin K is often not given in this situation, unless there is significant bleeding, as it is used to monitor the progress of the liver failure.
- FFP is not required unless there is bleeding.
- By the King's College Hospital criteria for liver transplantation for paracetamol-induced acute liver failure, she should be referred for early consideration for liver transplantation.
- Once the acute organic illness has settled, she will require a psychiatry assessment (Don't forget about this important component of her overall management!)

Rationale:

Diagnosis: Acute liver failure due a combination of alcohol and paracetamol overdose

The mode of presentation is highly suggestive of a reactive suicide attempt and a combination of paracetamol and alcohol is the most common in young women. The LFTs suggest an acute hepatitis and a transaminitis in the thousands suggests either an ischaemic or, in this case, a toxic aetiology. The coagulopathy and raised bilirubin are consistent with liver failure and a raised INR is one of the earliest indicators of paracetamol induced liver failure. Her ABG demonstrates a mixed respiratory and raised AG metabolic acidosis, which is likely to be attributable to a lactic acidosis, secondary to her liver failure.

- $AG = (Na) - (Cl + HCO_3 \text{ or } TCO_2)$. Normal 6-15mmol/L
- Expected $PaCO_2$ for metabolic acidosis: $mmHg = (HCO_3 \times 1.5) + 8$; $kPa = 0.2(HCO_3) + 1$

King's College Hospital criteria for liver transplantation for paracetamol-induced acute liver failure.

- $pH < 7.3$, or,
- $INR > 6.5$ and Serum creatinine $> 300\mu\text{mol/L}$ and West-Haven III-IV hepatic encephalopathy

Lab data – Case 23

Question:

A short synacthen test has been performed on one of your patients who is being treated for severe respiratory sepsis. How would you interpret the result?

Na 134 mmol/L	<u>Synacthen 0.25mg</u>
K 5.7 mmol/L	Cortisol T-0 411 nmol/L
Cl 105 mmol/L	Cortisol T-30 581 nmol/L
HCO_3 23 mmol/L	
Urea 5.9 mmol/L	
Creatinine 182 $\mu\text{mol/L}$	

Answer:

Interpretation: While the renal biochemistry and failure of cortisol to rise above the 600nmol/L threshold after synacthen suggest adrenal insufficiency in the setting of severe sepsis, the implications of this on management are much debated.

The concept of relative adrenal insufficiency is not universally accepted, with concerns about validation of measurement thresholds in critical illness and the interpretation of results obtained when critical illness has altered plasma proteins and total and free cortisol fractions. Therefore, the use of stress dose steroids remains controversial. My practice is to

Rationale:

Diagnosis: The renal biochemistry and result of the short synacthen test suggests adrenal insufficiency, which is a much debated pathology associated with critical illness and severe sepsis in particular.

Hyponatraemia + hypokalaemia + normal AG metabolic acidosis. A baseline cortisol (T-0, time zero) between 100 – 550nmol/L is neither specific for adrenal insufficiency nor adequacy. However, while a rise in cortisol level to less than 600nmol/L, or by less than 250nmol/L, by 30 minutes (T-30) after synacthen administration is consistent with adrenal insufficiency in an outpatient population, its implications for a critically ill patient is still hotly debated.

Lab data – Case 24

Question:

A 20 year old male is involved in a high speed car crash arrives in ICU after having internal fixation of a femoral fracture and application of external fixation to a complex pelvic fracture. Large volumes of fluids and blood products were infused in the Emergency Department then in the operating theatre. The arterial blood gas on arrival to ICU and the electrolytes sampled around this time are available. What is the likely cause of the acidosis and why? Analyse the results using concepts from the Stewart theory.

<u>Blood gases:</u>	<u>Electrolytes:</u>
FiO2 0.5	
pH 7.28	Na 146 mmol/L
paCO2 36 mmHg / 4.79 kPa	K 3.3 mmol/L
paO2 125 mmHg / 16.67 kPa	Cl 115 mmol/L
HCO ₃ 21 mmol/L	HCO3 21 mmol/L
Lactate 1.4 mmol/L	Urea 7.9 mmol/L
	Creat 90 µmol/L

	Albumin 33 mmol/L
	Phosphate 1.8 mmol/L

Answer:

In the setting of a high chloride and the clinical context of needing large volumes of fluid and blood product resuscitation the likely cause is a hyperchloraemic acidosis.

In this case:

- $SID = 21 + (0.28 \times 33 + 2.14 \times 1.8) = 21 + 9.24 + 3.85 = 34.1$
- This is less than 42, a low SID
- $SIG = [(146 + 3.3) - (21 + 115)] - (9.24 + 3.85) = (149.3 - 136) - 13.09 = 0.2$
- This is around 0, a normal SIG

Rationale:

The equations that are of practical relevance presented as follows:

- $SID = [HCO_3^-] + A^-$ (where normal is approximately 42)
- $SIG = \text{Anion gap} - A^-$ (where normal is approximately 0)
- where $A^- = 0.28 \times \text{Albumin (g/L)} + 2.14 \times \text{Phosphate (mmol/L)}$

• $\text{Anion gap} = [Na^+ + K^+] - [HCO_3^- + Cl^-]$

Lab data – Case 25

Question:

A 38 year old lady was admitted to the ICU 7 days ago for a massive PE, which was thrombolysed successfully and remains on IV anticoagulation. She is being weaned from the ventilator, having been treated with appropriate antibiotics for an aspiration pneumonia that occurred during the original intubation. The nurse raises a concern about apparent swelling of her right upper limb and shows you her most recent blood results. What specific laboratory tests would you request?

Na 141 mmol/L	Hb 12.9g/dL
K 4.3 mmol/L	WBC $8.6 \times 10^9/L$
Cl 97 mmol/L	MCV 82fl (normal 78-101 fl)

HCO ₃ 26 mmol/L	MCH 29pg (normal 25-35 pg/cell)
Urea 6.9 mmol/L	MCHC 33.6 (31 – 36 Hb/cell)
Creatinine 89 µmol/L	PLT 56 x 10 ⁹ /L
Glucose 6.3 mmol/L	PT 14.3 s (11.0 – 15.0s)
	INR 0.9
Bili 13 µmol/L	aPTT 44.9 s (24.0 – 33.0s)
ALT 29 U/L	Fibrinogen 3.02 g/L (2.00 – 4.00g/L)
AST 30 U/L	Thrombin time 14.6s (15.0 – 19.0s)
ALP 22 U/L	D-dimer <1.0 µg/ml (<1.00)
GGT 31 U/L	
Alb 37 g/L	
Prot 58 g/L	
Ca 2.38 mmol/L	
PO4 1.02 mmol/L	
Mg 0.97 mmol/L	

Answer:

Laboratory tests:

- HIT screen for heparin-PF4 complex antibodies. Confirmation by a positive activation test, using donor platelet serotonin release, is generally not required as it is more difficult and expensive due to the need for specific donor platelets. A positive PF4 assay with resolution of the platelet count after cessation of the heparin is considered confirmatory, although false negative PF4 assays can occur.
- Lupus anticoagulant
- SLE screen: ANA, anti-dsDNA, anti smooth muscle antibody, VDRL, anticardiolipin antibody, serum complement. Lupus anticoagulant is often positive in SLE.

Rationale:

Diagnosis: HIT type 2

The combination of a raised aPTT with the occurrence of a possible venous thrombosis (the swollen right upper limb) has a limited differential – HIT, lupus anticoagulant or an intravascular device, which has probably become infected, in someone on heparin. The presence, degree and timing of the thrombocytopenia favours HIT, although SLE is still a possibility

Lab data – Case 26

Question:

A 61 year old patient has been receiving continuous renal replacement therapy in your ICU for contrast induced acute renal failure. The nurse shows you the latest set of bloods for review. What is your response?

Na 137 mmol/L	Hb 11.3g/dL
K 3.8 mmol/L	WBC $7.7 \times 10^9/L$
Cl 95 mmol/L	MCV 80fl (normal 78-101 fl)
HCO ₃ 28 mmol/L	MCH 30pg (normal 25-35 pg/cell)
Urea 15.0 mmol/L	MCHC 33.9 (31 – 36 Hb/cell)
Creatinine 219 $\mu\text{mol/L}$	PLT $156 \times 10^9/L$
Glucose 8.3 mmol/L	PT 12.6 s (11.0 – 15.0s)
Bili 10 $\mu\text{mol/L}$	INR 0.8
ALT 23 U/L	aPTT 31.0 s (24.0 – 33.0s)
AST 26 U/L	
ALP 34 U/L	
GGT 45 U/L	

Alb 33 g/L	
Prot 51 g/L	
Ca 1.58 mmol/L	
iCa 0.81mmol/L	
PO4 0.82 mmol/L	
Mg 0.57 mmol/L	

Answer:

Response: Check the pre-filter citrate infusion rate. Increase the post filter calcium infusion rate.

Rationale:

Diagnosis: Biochemical effect of citrate anticoagulated dialysis.

In general, CRRT dialysis circuits require some form of anticoagulation, in order to preserve filter life by minimising filter thrombosis. Typically this is done with heparin, which usually results in an elevation of the aPTT, even if post filter protamine is used (regional heparinisation). Alternatives include fondaparinaux, danaparoid, a hirudin analogue (eg bivalirudin, lepirudin) and citrate. There has been a resurgent interest in citrate dialysis recently and, of all of the above anticoagulant alternatives, only citrate excess results in a hypoglycemic hypomagnesaemia. The mildly raised HCO_3^- is likely to be due to the hepatic metabolism of systemic citrate

Lab data – Case 27

Question:

This 70 year old female presented with dizziness and had a history of recent syncopal episodes. On examination she had a loud ejection systolic murmur noted which radiated to her carotid arteries. An echocardiogram demonstrated severe aortic stenosis with features suggesting a calcification bicuspid valve. She was admitted for surgery and the following pre-operative blood results were noted:

WBC $5.0 \times 10^9/\text{L}$ (3.5-10)	HCT 0.16 (normal 0.35-0.40)
RBC $1.94 \times 10^9/\text{L}$ (3.8-5.1)	MCV 70 fl (normal 78-101 fl)

HGB 48 g/L (120-150)	MCH 22 pg/cell (normal 25-35 pg/cell)
----------------------	---------------------------------------

a) Interpret the results. What is the most common cause of this picture? What test will you order to confirm your suspicion?

b) The patients Iron studies were performed.

Iron 3 $\mu\text{mol/L}$ (low)

Total Iron Binding Capacity 92 $\mu\text{mol/L}$ (high)

Ferritin 6 $\mu\text{g/L}$ (low)

Do these results confirm your suspected diagnosis? What is a single unifying diagnosis that would tie together this picture and severe aortic stenosis?

Answer:

a) There is a marked microcircuit, hypochromic anaemia. The most likely cause is iron deficiency anaemia. Iron studies will be helpful.

b) Yes. The results are consistent with Iron deficiency anaemia. There are a number of potential causes of this that need investigating, but angiodysplasia is a known association with severe aortic stenosis where it is termed Heyde's Syndrome. It is thought that von Willebrand factor is proteolysed due to high shear stress from turbulent flow across the diseases aortic valve, increasing the risk of bleeding from intestinal telangiectasias that are increasingly common with advancing age.

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Lab data – Case 28

Question:

A 65-year-old man underwent a Whipple's procedure for resection of a pancreatic adenocarcinoma. An anastomotic leak and pancreatic fistula complicated this. Total parenteral nutrition was provided. After a month of TPN trace elements were ordered and the results shown:

Plasma/serum chromium 5 nmol/L (1-26 nmol/L)

Plasma/serum selenium 0.9 $\mu\text{mol/L}$ (0.9-1.4 $\mu\text{mol/L}$)

Plasma/serum zinc 2.6 $\mu\text{mol/L}$ (10-19 $\mu\text{mol/L}$)

Plasma/serum copper 14.8 $\mu\text{mol/L}$ (12-22 $\mu\text{mol/L}$)

Blood manganese 90 nmol/L (60-350 nmol/L)

Blood selenium 1.1 $\mu\text{mol/L}$ (1.2-2.1 $\mu\text{mol/L}$)

Comment on the findings.

Answer:

The results suggest a deficiency of zinc and to a lesser degree selenium.

Both trace elements are known to commonly fall in critically ill patients, including surgical patients requiring TPN. Both are important antioxidants involved in host defense against free radicals. Zinc is also involved in wound healing and glycaemic control. The risks, benefits and most appropriate regimen for replacing trace elements in the critically ill patient remains unclear although this is an area of current active research

Lab data – Case 29

Question:

A 22 year old lady has been in the ICU for management of her septic shock secondary to ascending cholangitis. Overnight, as her therapy was being weaned she received an accidental bolus of noradrenalin, resulting in a brief period of significant hypertension. Subsequently, she has been complaining of a severe headache, requiring increasing boluses of opiate analgesia. A head CT was performed the following day and has been reported as normal. A lumbar puncture is performed and you are shown the results. What is your interpretation? What investigation would you request next?

<u>CSF</u>	<u>Blood</u>
Protein 0.59g/L (0.15 – 0.45g/L)	Glucose 7.2mmol/L
Glucose 6.9mmol/L (2.5 – 5.6mmol/L)	
	Hb 12.9g/dL
Appearance: clear, xanthochromic supernatant	WBC $13.5 \times 10^9/L$
	PLT $435 \times 10^9/L$
RBC $5340 \times 10^9/ml$	
Polymorphs $8 \times 10^9/ml$	
Mono $6 \times 10^9/ml$	

Answer:

Diagnosis: Subarachnoid haemorrhage, secondary to catecholamine surge

Investigation: A CT angiogram, to look for cerebrovascular aneurysms.

Rationale:

A severe headache after a period of significant hypertension raises the possibility of an intracranial haemorrhage (SAH, intracerebral) or a carotid or vertebral artery dissection. A head CT should reliably show an intracerebral haemorrhage, but if there is a delay in performing it, a subarachnoid haemorrhage may be missed due to reduced sensitivity. However, as the sensitivity of a head CT for an SAH declines over the initial 24 hours, the sensitivity of an LP improves. The red cell to white cell ratio ($>300 - 500:1$) of the sample above does not support an infective aetiology

Lab data – Case 30

Question:

A 32 year old gentleman is admitted to your ICU for management of his septic shock following a right sided percutaneous nephrostomy tube insertion for obstructive ureterolithiasis which has resulted in right sided pyelonephritis. He has been commenced on empiric ceftriaxone and is on $0.7\mu\text{cg/kg/min}$ of noradrenalin. The following day a microbiology report is phoned through to the department and handed to you. What would you do next?

Urine microscopy

RBCs $>100 \times 10^9/\text{ml}$

WBC $> 100 \times 10^9/\text{ml}$

Epithelial $< 10 \times 10^9/\text{ml}$

Organisms seen

Culture: Pure growth E.coli

This organism has tested positive for ESBL

Answer:

Intervention: Change the cephalosporin antibiotic to a carbapenem; e.g. meropenem, imipenem.

Rationale:

ESBL organisms, typically gram negative enterobacteriaceae such as E.coli and klebsiella, have a plasmid transmission mediated β -lactamase, rendering them resistant to β -lactam antibiotics. The use of a β -lactamase inhibitor such as clavulanate or tazobactam has not resulted in reliable activity against these organisms. They are often also multiply resistant to quinolones and aminoglycosides. Carbapenems have had reliable activity against ESBL organisms despite persistent use.

Lab data – Case 31

Question:

A 79 year old lady is in your ICU being treated for severe necrotising pancreatitis. A blood culture that was taken following a new fever is returned. What therapeutic strategy would you choose?

Blood culture

Site: Blood

Culture: 10^3 cfu Enterococcus faecium (Van-A) isolated

Site: CVC

Culture: 10^4 cfu Enterococcus faecium (Van-A) isolated

Answer:

Strategy:

- Replace all vascular catheters, ideally with a 72 hour gap if feasible, and consider using an antibiotic impregnated catheter
- Send repeat blood cultures from peripheral sites, the old catheters prior to removal and the new catheters once sited. Also send the old catheter tips for culture.

- Start synergid or tygecycline, given the presence of a septicaemia.
- Move the patient to an isolation room and employ full barrier nursing procedures, especially hand washing.

Rationale:

Diagnosis: Vancomycin resistant enterococcus faecium catheter related blood stream infection.

Definitions for a catheter related blood stream infection (CRBSI) vary and include growth of >15 colonies (semiquantitative analysis), or 10^3 + cfu (quantitative analysis), from a distal or proximal catheter segment, or isolation of 5 - 10 times the colony count from a catheter aspirated blood sample as from a peripheral sample, or positive growth from the catheter sample occurs 2 hrs before peripheral sample, in the presence of features of infection. Defervescence of the fevers after removal of a suspect vascular catheter is also accepted as evidence of a CRBSI.

There are 3 levels of vancomycin resistance amongst enterococcal species

- Van-A: High level resistance. Cannot use Vancomycin or Teicoplanin. Use tygecycline (E. faecium & faecalis) or synergid (E. faecium only)
- Van-B: Vanc resistance induceable, but can use Teicoplanin, though long term use may result in resistance
- Van-C 1 - 3: Low level resistance

-

• Lab data – Case 32

• Question:

- A 74 year old gentleman is admitted to the ICU for management of septic shock due to a community acquired pneumonia. He is difficult to ventilate and a CXR shows a large left sided pleural effusion. This is therapeutically tapped and the cloudy fluid sent for analysis. What is your interpretation of the results?

<u>Pleural fluid</u>	<u>Blood</u>
Glucose 0.1 mmol/L	Urea 12.6 mmol/L
Protein 54 g/L	Creatinine 173 μ mol/L
LDH 4522 U/L	Na 135 mmol/L
pH 7.12	K 5.0 mmol/L
	Cl 102 mmol/L
WBC > 10×10^9 /ml	HCO ₃ 24 mmol/L
RBC > 10×10^9 /ml	

Gram stain: Polymorphs + +

Bili 10µmol/L

ALT 23 U/L

AST 26 U/L

ALP 34 U/L

GGT 45 U/L

LDH 202 U/L

Protein 64 g/L

Albumin 20 g/L

Glucose 9.2 mmol/L

-
-

- **Answer:**

- Diagnosis: Empyema

- **Rationale:**

- The patient is being treated for a pneumonia, which acts as the source for the empyema. The tapped fluid is cloudy and, by Light's criteria (Effusion to serum protein ratio > 0.5, effusion to serum LDH > 0.6, effusion LDH > 2/3rds upper limit of normal serum LDH), suggests an exudative effusion. Other indicators of an exudate include effusion protein > 30g/L and a serum to effusion albumin gradient < 1.2 g/L. The low effusion pH and extremely low effusion glucose are very suggestive of an empyema as a cause of the effusion.

Lab data – Case 33

Question:

A 59 year old patient has been in ICU for 6 days, subsequent to an out of hospital cardiac arrest. He has shown a slow neurological recovery and is due to have a tracheostomy placed to facilitate weaning from his ventilator. He began to have febrile episodes on day 4 of his admission and his CXR shows a new right middle lobe infiltrate. A non-directed bronchoalveolar lavage was sent for analysis and the results have returned. What strategies would you employ to minimise the risk of this complication?

Sputum

Appearance: Mucopurulent

RBCs $>10 \times 10^9/\text{ml}$

WBC $> 100 \times 10^9/\text{ml}$

Epithelial $< 10 \times 10^9/\text{ml}$

Organisms seen. GPC in clusters.

Culture: Staph aureus (Mec-A gene detected)

Answer:

Strategies:

1. For prevention of VAP

- Avoid unnecessary intubation
- Minimise duration of invasive ventilation
- Head up 30 - 45 degrees
- Feed enterally rather than parenterally. Benefit possibly offset by presence of NG tube, compromising lower oesophageal sphincter function
- Maintain normoglycaemia, especially DM
- The role of supraglottic suction catheter is not universally accepted as yet
- The roles of selective digestive decontamination or selective oral decontamination remain controversial

2. For prevention of transmission of an MRO

- Adherence to barrier nursing principles
- Hand washing before and after patient contact
- The use of alcohol based hand rubs
- Adherence to the principles of appropriate use of antibiotics in order to minimise the evolution of colonisation to infection
- Minimising the use of invasive devices
- Eliminating infection reservoirs

Rationale:

Diagnosis: Late onset MRSA ventilator-associated pneumonia (VAP)

- A ventilator-associated pneumonia is defined as pneumonia occurring more than 48 hours of initiating mechanical ventilation or within 48 hours of extubation (American Thoracic Society Guidelines definition). It is further classified as early (day 1 – 4 post intubation, community acquired organisms) or late (day 5 or more post intubation, nosocomial organisms), which alters the spectrum of organisms likely to be involved.
- The Mec-A gene confers methicillin resistance on to staphylococcus aureus (MRSA).

• Lab data – Case 34

• Question:

•

- A 63 year old patient who has been ventilated for 8 days for ARDS of unknown aetiology has had a resurgence of febrile episodes. His sputum samples persistently return a growth of a gram negative rod despite therapeutic gentamicin levels and adequate doses of Piperacillin-Tazobactam. What implications does this have for the ICU?

• Answer:

- The concern is the emergence of a multidrug resistant (MDR) Gram negative organism (e.g. Pseudomonas, ESBL, ESCAPM agent, Stenotrophomonas maltophilia). Some acquire resistance, others, like stenotrophomonas, are inherently multiply-resistant environmental gram negative organisms. Its isolation suggests that this patient has been on prolonged broad spectrum antibiotics. The patient must be isolated and strict barrier nursing and contact precautions must be taken in order to prevent horizontal transmission to other patients. Transmission to immunosuppressed, critically ill patients is devastating, especially inherently multiply resistant organisms, such as stenotrophomonas which only have a limited range of effective antibiotics available for their treatment.
- The second concern is that the organism cannot be reached by the antibiotics if, for example, an abscess or a loculated empyema has formed. This requires a focussed assessment in order to determine the most appropriate treatment

Lab data – Case 35

Question:

A 45 year old renal transplant patient is admitted to hospital with fevers, a dry cough and a single episode of haemoptysis. An ICU consult is sought when, on the ward, his oxygen saturation deteriorates and his work of breathing increase, despite increasing his FiO₂ to 15L/min via non-rebreather mask. On examination, he is in moderate respiratory distress and hypoxic with a tachycardia and normal blood pressure. His CXR shows bilateral patchy infiltrates. He is intubated and a bronchoscopic BAL is performed. List the possible responsible organisms and the antimicrobial agent you would commence.

Answer:

Bacterial	Antimicrobial agent
• Typical	• Benzylpenicillin, ampicillin or ceftriaxone + macrolide (e.g. azithromycin)

<p>community acquired organisms (strep, haemophilus, moraxella)</p> <ul style="list-style-type: none"> Atypical non-zoonotic community acquired organisms (legionella, mycoplasma, chlamydia pneumonia) Atypical zoonotic community acquired organisms (chlamydia psittaci, Q fever, Francisella tularensis) High risk community acquired pneumonia (staphylococcus, enteric gram negative organisms) Nosocomial organisms TB <p>Viral</p> <ul style="list-style-type: none"> CMV HSV Chicken pox <p>Fungal</p> <ul style="list-style-type: none"> Pneumocystis jirovecii (formerly PCP) Invasive aspergillosis Invasive candidiasis 	<ul style="list-style-type: none"> Ampicillin + macrolide (e.g. azithromycin) Doxycycline, moxifloxacin or a macrolide (e.g. azithromycin) Flucloxacillin Ceftriaxone or moxifloxacin Timentin + gentamicin ± vancomycin Rifampicin + isoniazid (pyridoxine) + pyrazinimide + ethambutol Ganciclovir Aciclovir or Valaciclovir Aciclovir or Valaciclovir Co-trimoxazole (Bactrim) Voriconazole Generally fluconazole sensitive, unless <i>C. glabrata</i> or <i>C. krusei</i>, in which cases use amphotericin B or voriconazole
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Image data

Radiology and other imaging modalities are another form of data question where candidates trip themselves up by looking for the “trick”. Often candidates dance around the abnormality, spending time on a template presentation or picking out lesser findings, before getting on with the point scoring. It may be helpful to adopt a lead in phrase, such as:

“The most striking abnormality is the large left side pleural effusion, for which there are several diagnostic possibilities. However, going through this CXR in detail, I can see that it is an AP film that is well centred, with adequate penetration....”

Such an opening line tells the examiners that you have identified the main problem, but would not be distracted by it and still perform a thorough evaluation of the film. This is usually enough for them to cut you off, give you the marks and move on to more point scoring questions.

Tips for imaging Questions

1. Pay attention to the case history that is presented to you. It will often direct you to the findings that you should be looking for. Then consider why you have been given the particular study that is in front of you. For example, a patient with an acute abdomen and instability with a contrast enhanced CT of the abdomen should prompt close inspection of the abdominal aorta, pancreas, kidneys, retroperitoneum and bowel pattern and a specific search for intraperitoneal gas, free fluid in dependant areas, renal or ureteric calculi and fat stranding around the viscera.
2. If there is a stand out abnormality from the moment you see the image, comment upon it, but don't be blinded by it and forget to look for other abnormalities; e.g. a grossly oedematous pancreas that draws attention away from a small gallstone, which may be the aetiological agent and influence subsequent management

Imaging data – Case 1

Question:

This 62 year old man presented with a 3 day history of cough and fevers. Describe his CXR and list three differential diagnoses for this appearance.

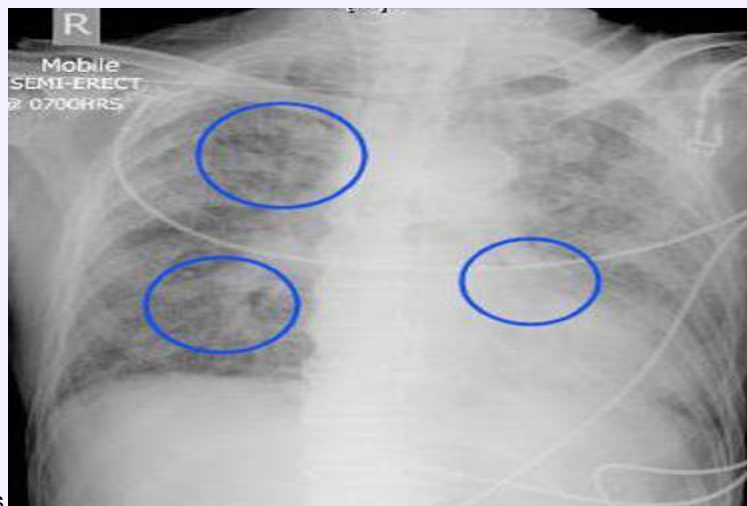


Answer:

Widespread interstitial infiltrates throughout both lung fields with superimposed airspace change particularly in both upper zones and the left lower behind the heart. There are also changes that are consistent with air bronchograms (Blue circles), suggesting consolidation.

The main differential diagnoses include:

1. Infection: viral and atypical bacterial infections
2. Pulmonary fibrosis: acute or chronic
3. Cardiogenic and non-cardiogenic pulmonary oedema
4. Drug reactions



5. Lymphangitis carcinomatosa

Imaging data – Case 2

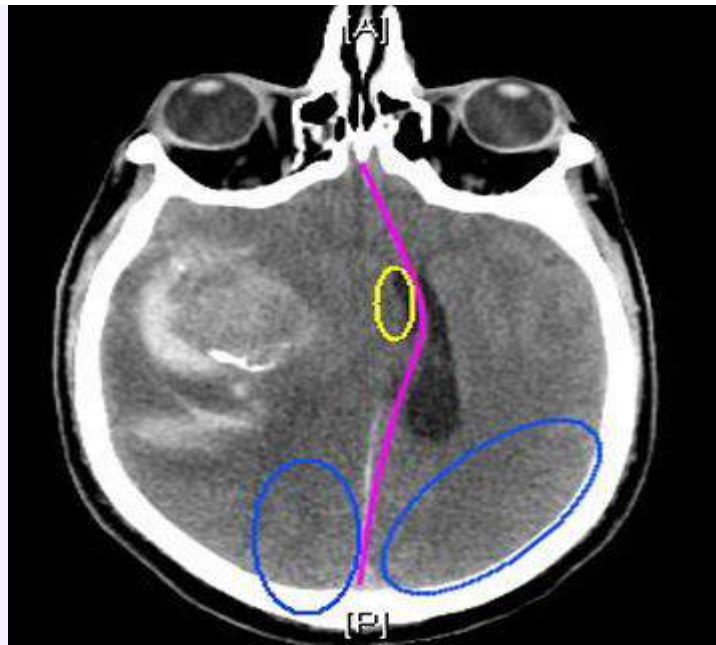
Question:

This elderly gentleman was admitted with a known right giant middle cerebral artery aneurysm. He deteriorated on the ward and his repeat CT head showed bleeding. Identify the features of mass effect.



Answer:

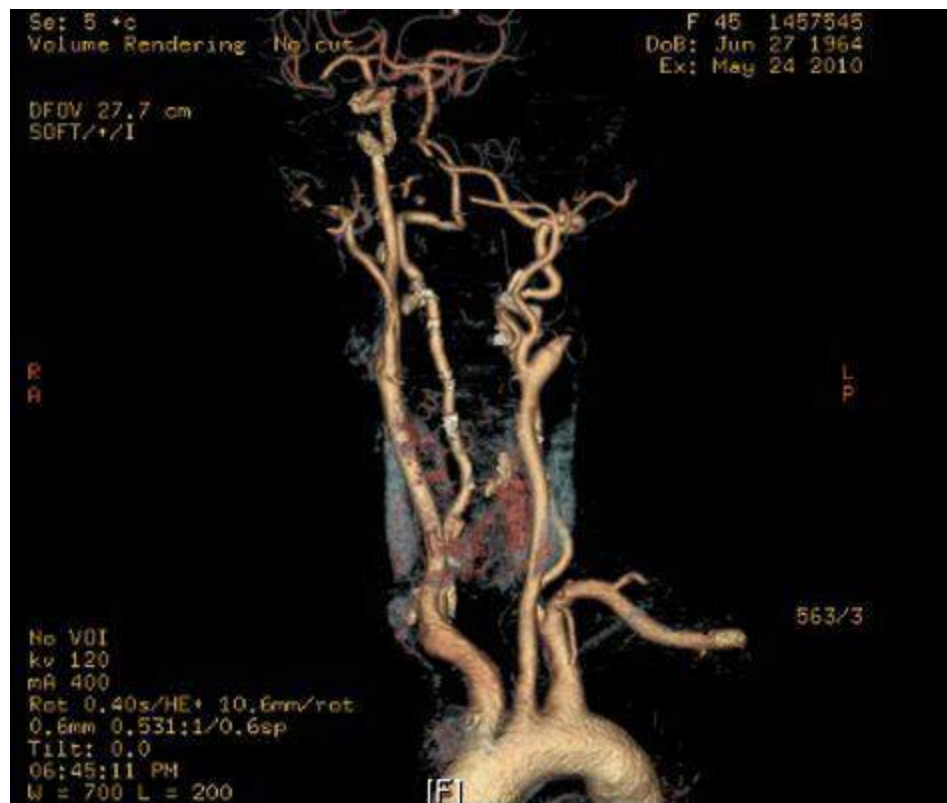
- Midline shift (Pink line)
- Loss of grey white differentiation (Blue ellipse)
- Obliteration right lateral ventricle (Yellow ellipse)



Imaging data – Case 3

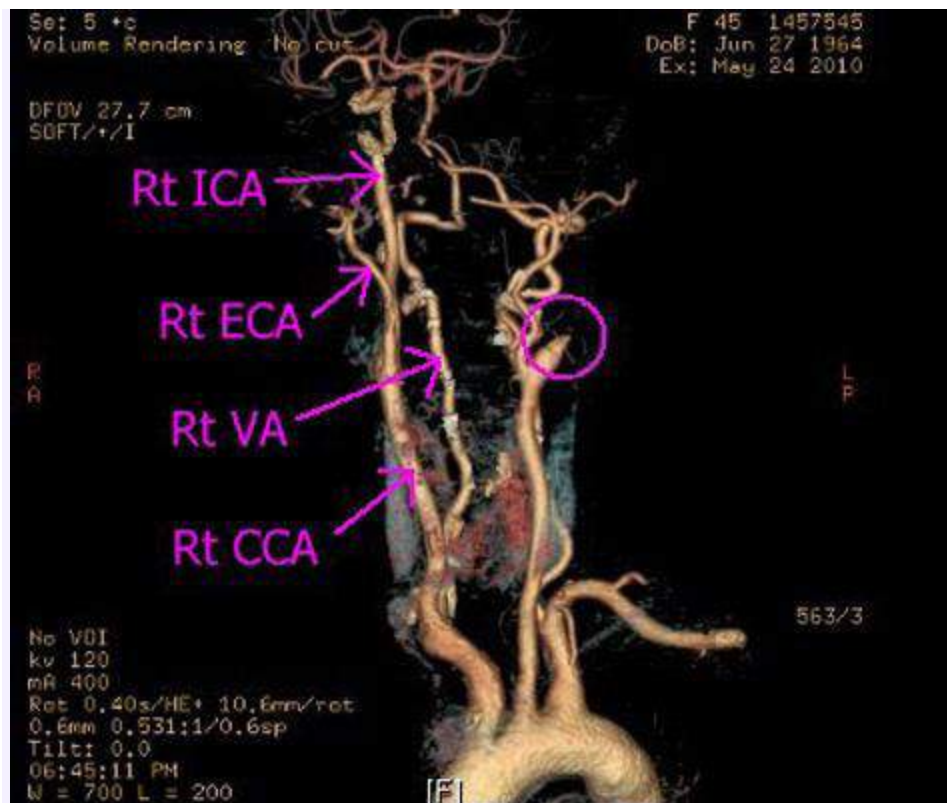
Question:

This lady presented with a sudden onset of loss of vision in her left eye, dysphasia and right arm numbness. Can identify a lesion on her CT angiogram to explain this presentation?



Answer:

There is a "cut-off" sign with no flow in the left internal carotid artery just distal to the bifurcation of the common carotid, consistent with a dissection in this clinical conte



Rt ICA = Right internal carotid artery

Rt ECA = Right external carotid artery

Rt VA = Right vertebral artery

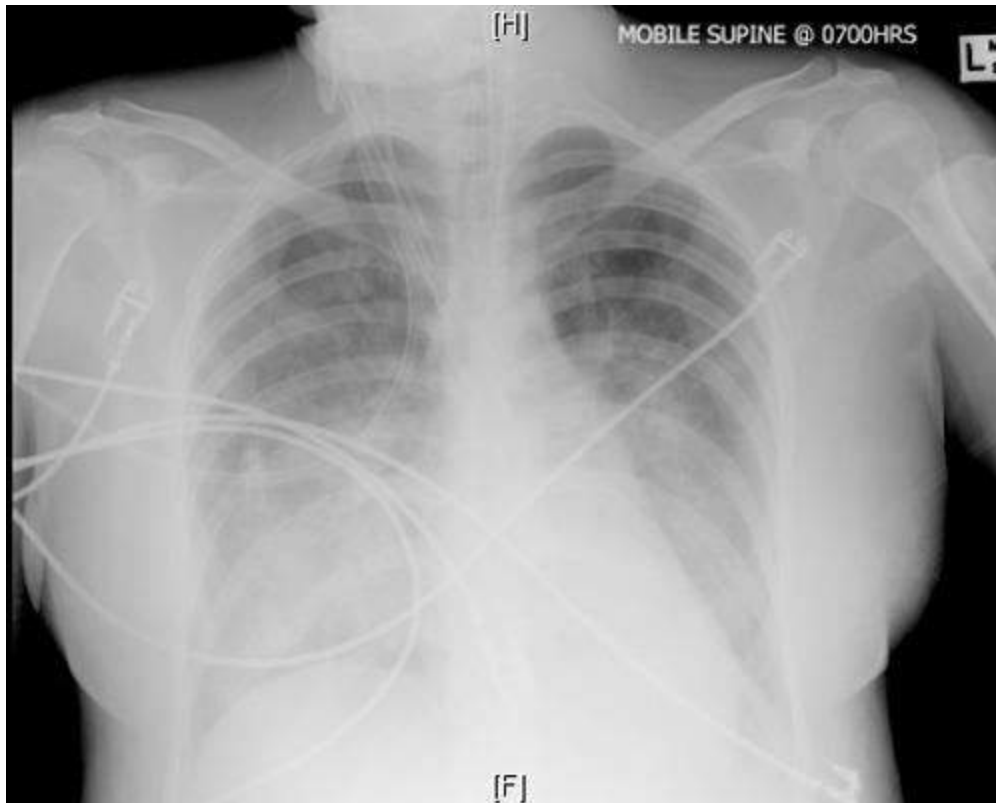
Rt CCA = Right common carotid artery

Pink circle = "Cut-off" point at proximal left ICA

Imaging data – Case 4

Question:

This 28 year old G3P1 failed to progress in the second stage of labour and required a forceps delivery. This was complicated by a postpartum haemorrhage of at least 1 litre requiring resuscitation and multiple blood products. She eventually required ligation of both internal iliac arteries for uncontrollable bleeding, and the uterus was tamponaded with a Bakri balloon. Provide a differential diagnosis for her CXR on admission to ICU.

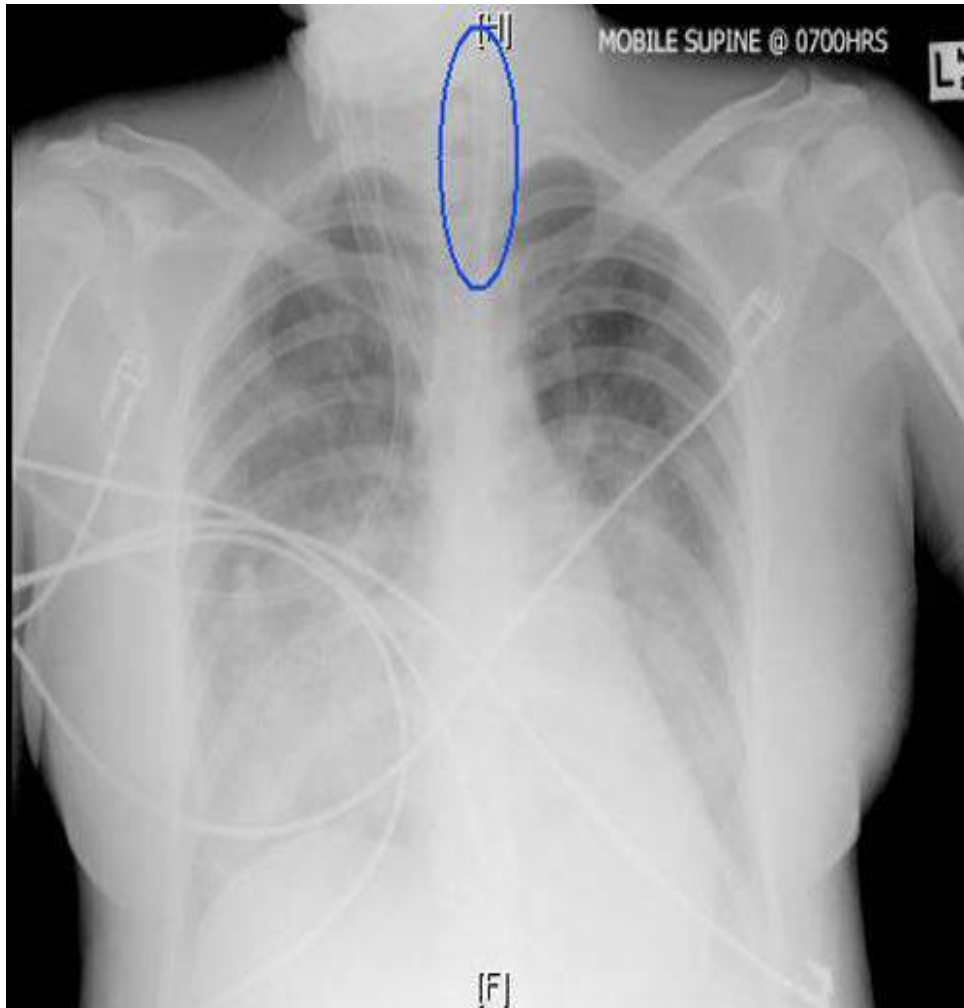


Answer:

The causes of alveolar oedema in this patient include the following:

1. TRALI
2. Fluid overload secondary to massive resuscitation
3. ARDS secondary to shock
4. Amniotic fluid embolus
5. Massive aspiration pneumonitis

Also note that the endotracheal tube is high in this CXR situated well above the clavicular heads (Blue ellipse)



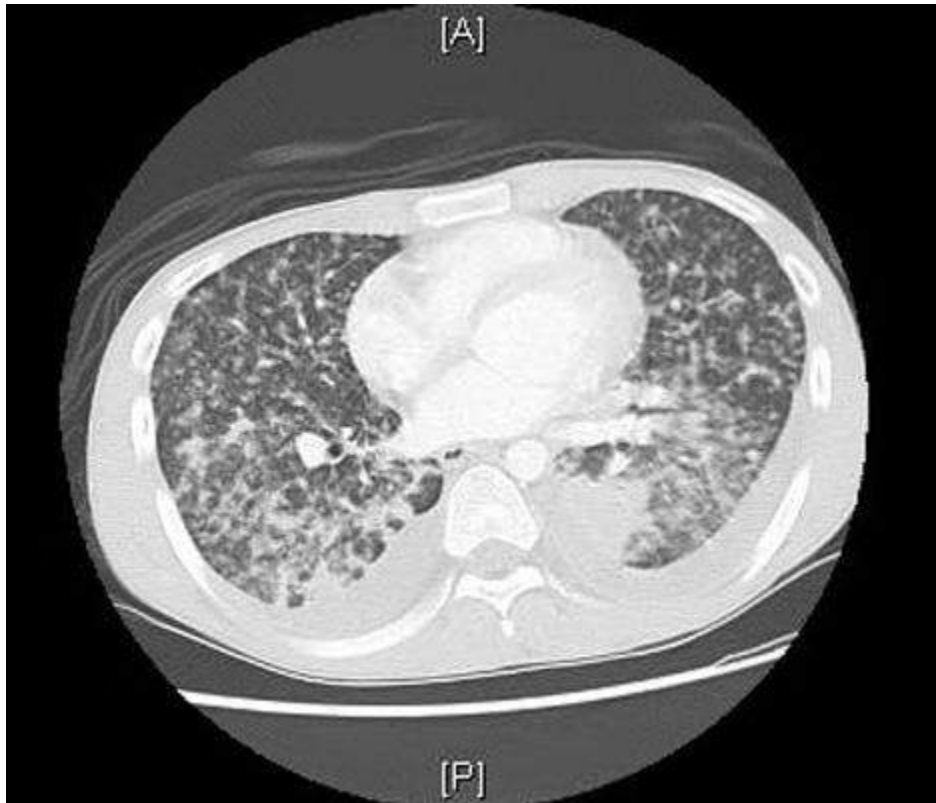
Imaging data – Case 5

Question:

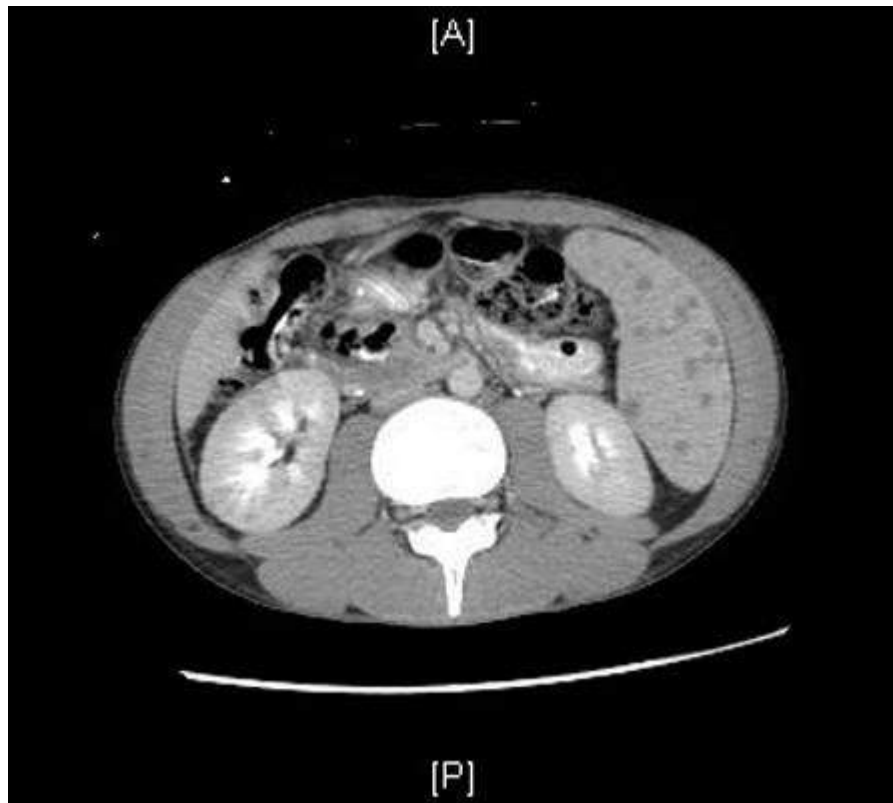
This 22 year old Korean exchange student was admitted to ICU with a febrile illness and respiratory distress. What diagnosis would you consider and why?



(A)



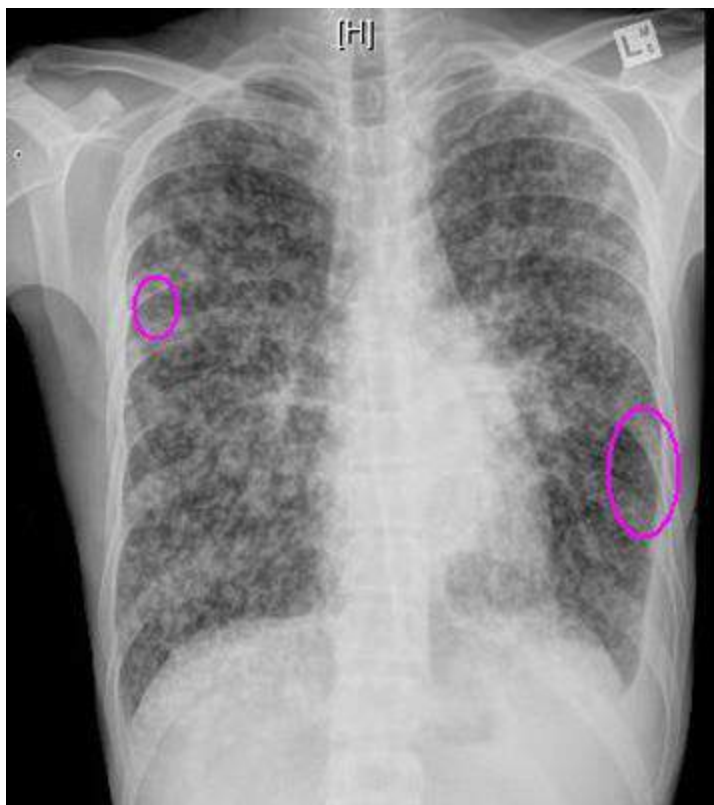
(B)



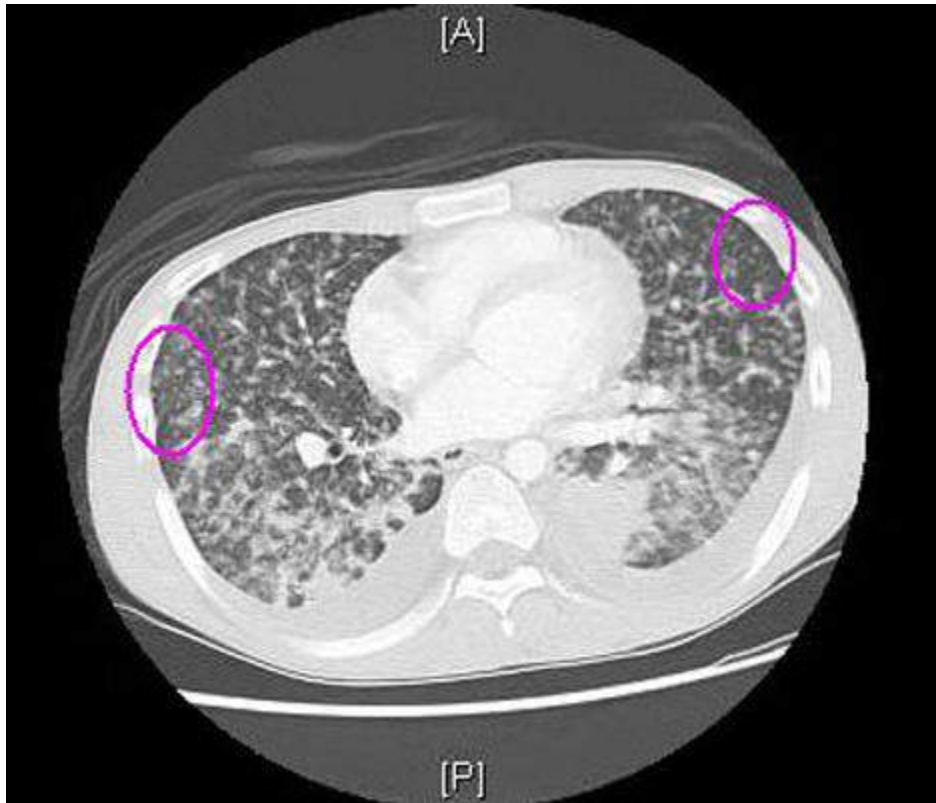
(C)

Answer:

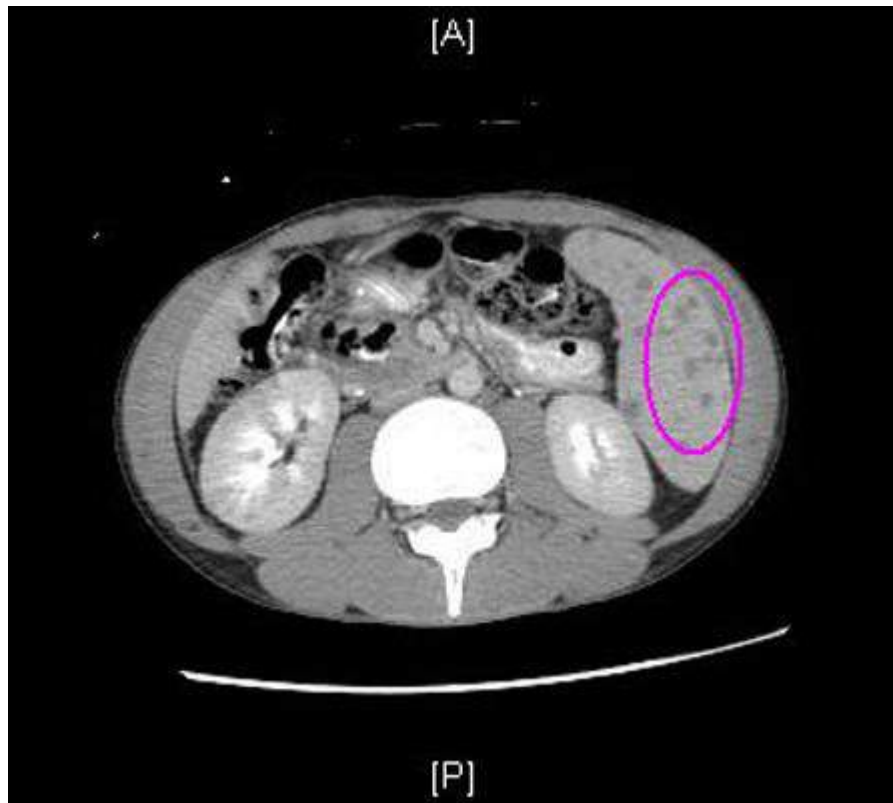
This images are highly suggestive of miliary TB which classically spreads to multiple organs with classic small, well-defined nodular opacities, the size of 'millet seeds' (Pink ellipses). The patient fits a risk factor profile for this disease.



(A)



(B)



(C)

Question:

This 76 year old man with a previous C4-6 fusion, fell off a stool whilst changing a light bulb. He had evidence of quadraparesis which appeared to be more marked in his upper limbs compared with lower limbs. Identify the key features on this T2 sagittal MRI, and how does this explain the clinical presentation?



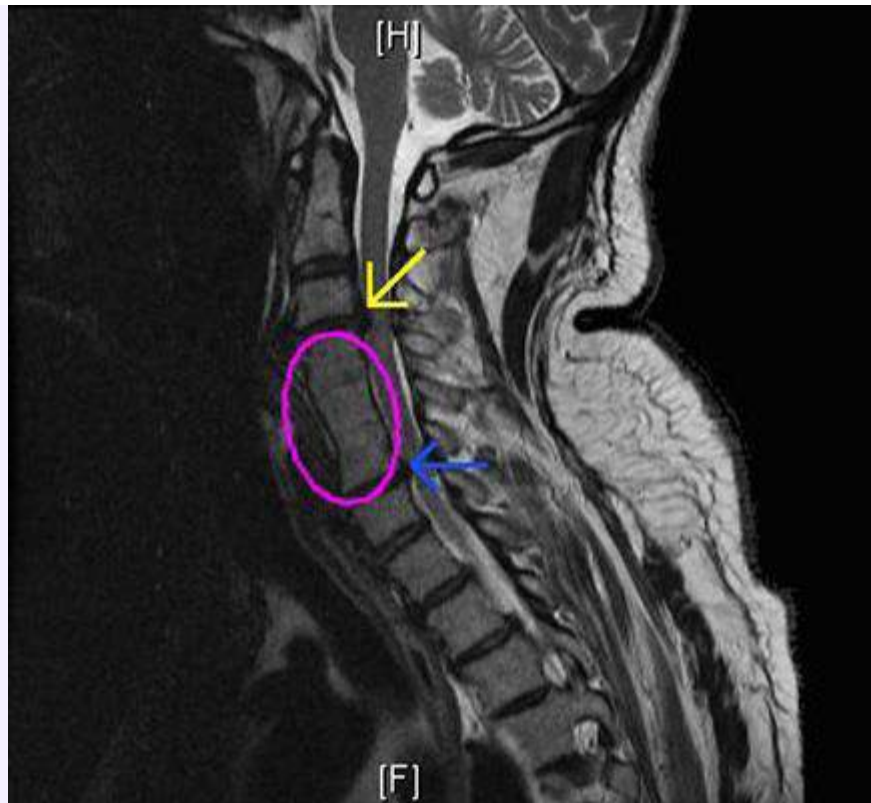
Answer:

Interbody fusion of C4-6 vertebrae inclusive (Pink ellipse).

C3/4 there is posterior disc protrusion (Yellow arrow).

C6/7 less marked posterior disc protrusion (Blue arrow).

The clinical features are consistent with a central cord syndrome, which occurs more frequently in the elderly with cervical spondylosis complicating a hyperextension injury.



Imaging data – Case 7

Question:

This 25 year old man has recently returned from a 6 month trip backpacking around South Asia and presents with fevers, diarrhoea and vomiting and right upper quadrant pain. What is the differential diagnosis for the main finding on his CT abdomen?

**Answer:**

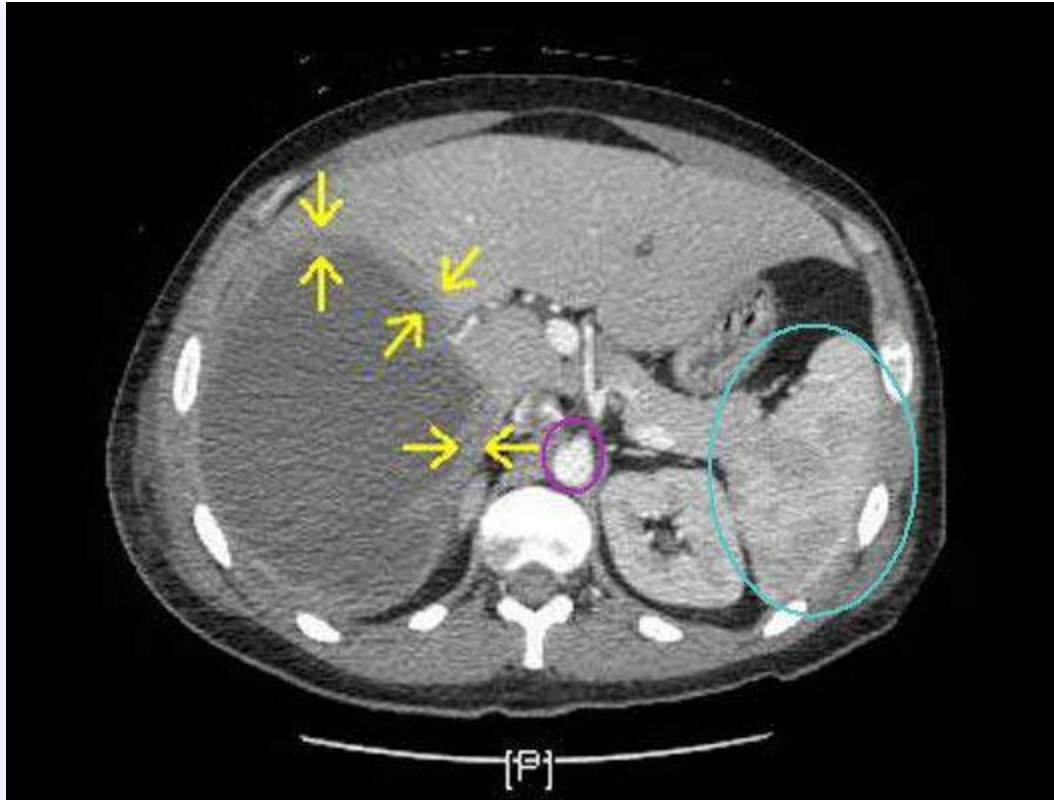
Bacterial infection, usually haematogenous spread via the portal vein from an intra-abdominal source.

Amoebic infection, classically *Entamoeba histolytica*.

Fungal infection, classically *Candida*.

Rationale:

This CT demonstrates a single large liver abscess, with a thick encircling wall (Yellow arrows). The organism responsible does not appear to be a gas former, though this is only a single CT slice. The spleen (Blue ellipse) appears mottled as this contrast CT has been taken during the arterial phase – Contrast can clearly be seen in the descending aorta (Pink ellipse), but not the IVC or hepatic portal vein.



Liver abscess CT - Marked

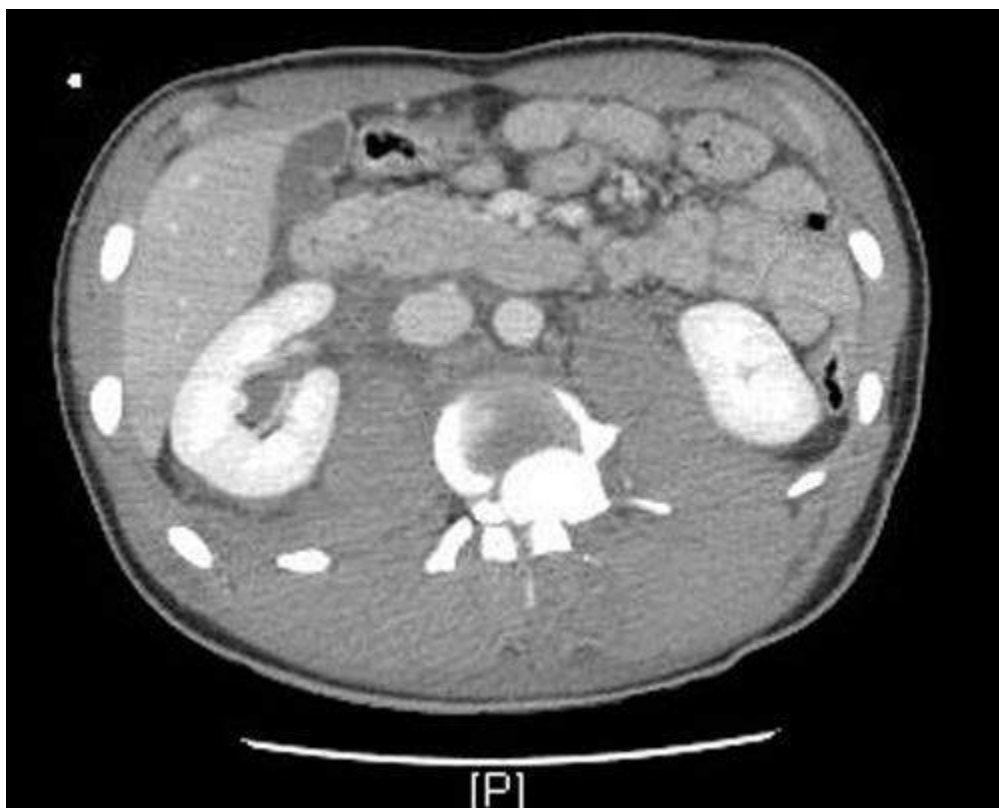
Imaging data – Case 8

Question:

This 50 year old man was a backseat restrained passenger traveling in a car that collided with a tree at speed. He suffered multiple injuries and on the basis of his imaging below what would expect to find on clinical examination? What associated injury would you suspect?



(A)



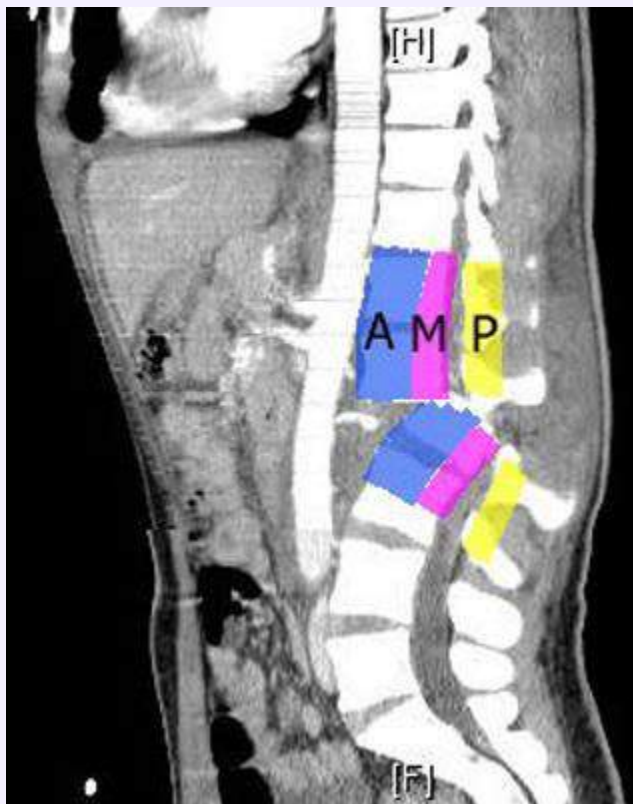
(B)

Answer:

The CT scans show a severe comminuted three column fracture dislocation of L2 classic for a seatbelt injury.

Injuries to L2 frequently damage the conus medullaris with the main clinical findings being lower limb paresis, bilateral preservation of the knee jerks, loss of ankle jerks, sensory disturbance localised to the perianal area, reduced anal tone and urinary retention. This should be differentiated from the cauda equina syndrome which describes lesions below this level.

The classically associated injury is a duodenal perforation.

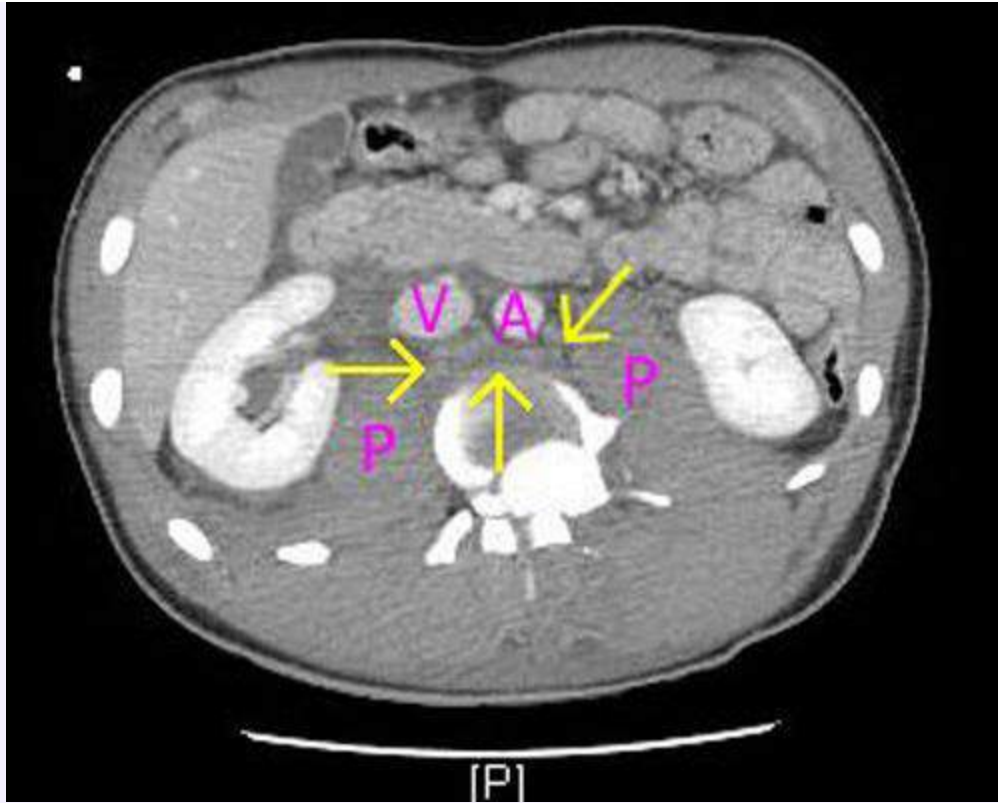


(A)

A = Anterior column

M = Middle column

P = Posterior column



(B)

P = Paraspinal muscle

V = IVC

A = Aorta

Arrows = haematoma margins

Imaging data – Case 9

Question:

This elderly lady, who is on warfarin with a complex cardiac history, was gardening when she fell over and struck her head. She presented to ED confused with obvious left sided hemiplegia and left sided facial droop. Her CT is shown below. Describe the main findings and your management options.



Answer:

Intraparenchymal haemorrhage (Pink ellipse) in the right parietal lobe. Mass effect with complete obliteration of the occipital horn of the right lateral ventricle (Blue arrow). Midline shift (Yellow line), loss of white grey matter differentiation (Blue ellipse).

Management options include ceasing her warfarin and reversal of anticoagulation with Prothrombinex or fresh frozen plasma.

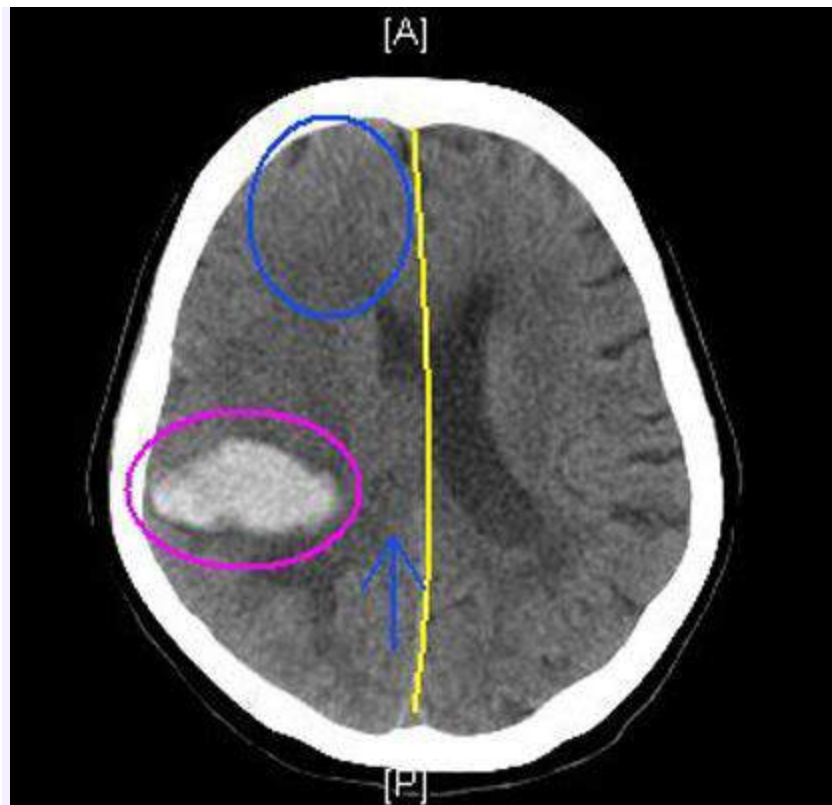
The role of surgical intervention remains controversial (STICH trial), especially as this likely to be her dominant hemisphere. Given her confused state, placement of an ICP monitor is justifiable.

Further management is directed towards controlling sources of secondary injury such as hypoxia, haemodynamics, seizure and metabolic control.

Her head should be elevated to at least 30 degrees, allowing for any spinal precautions necessary.

Close monitoring for evidence of further bleeding or hydrocephalus.

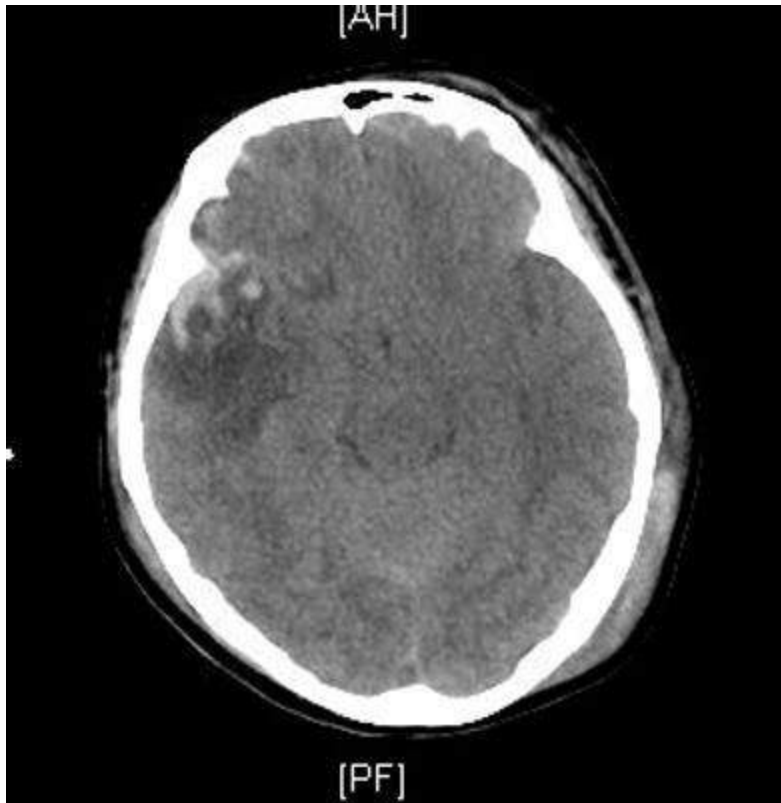
Involvement of a cardiologist and neurosurgeon regarding future anticoagulation will be important.



Imaging data – Case 10

Question:

This young lady was crossing a busy road when she was hit by a car. Her main injury was a severe traumatic brain injury and her CT scan is as follows. 24 hours into her ICU admission her ICP is 30, list your possible management strategies.



Answer:

The CT image shows haemorrhagic contusion of the right temporal lobe.

Her management can be divided into medical and surgical strategies.

Medical:

1. Midline head position with care not to obstruct venous drainage, with thirty degree head elevation.
2. Sedation.
3. C02 within normal range.
4. Osmotherapy – mannitol or hypertonic saline

Surgical:

1. Decompressive craniectomy (DECRA trial 2011 suggests better ICP control, shorter ICU stay, no difference in mortality, better moderate disability outcome, but worse severe disability outcome and higher incidence of hydrocephalus)

Other:

1. Seizure control, typically with IV midazolam initially and then phenytoin or leviratracetam
2. Neuromuscular paralysis
3. Therapeutic hypothermia (Controversial)
4. Thiopentone coma (Controversial)

5. Imaging data – Case 11

6. Question:

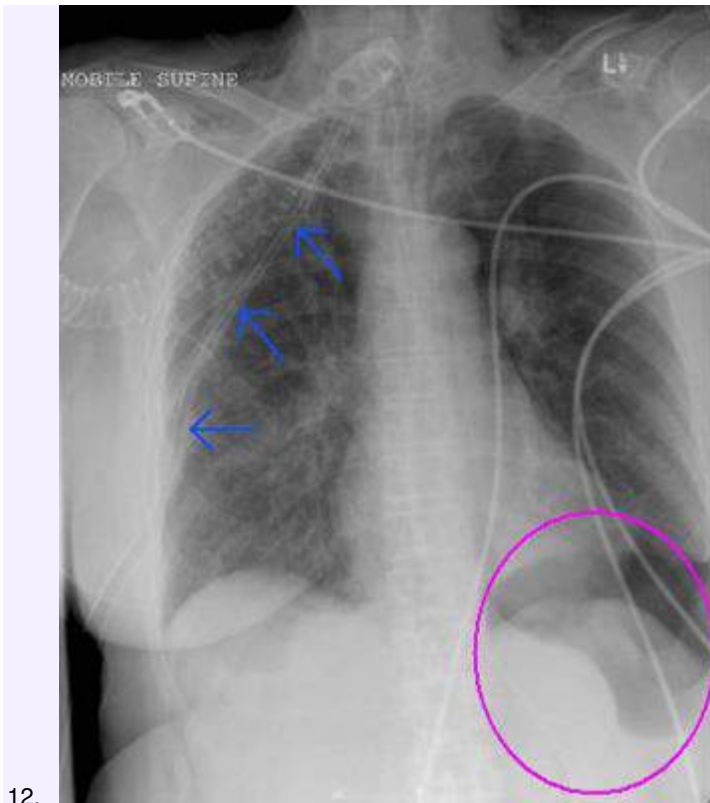
7. Why was this patient difficult to ventilate?



8.

9. Answer:

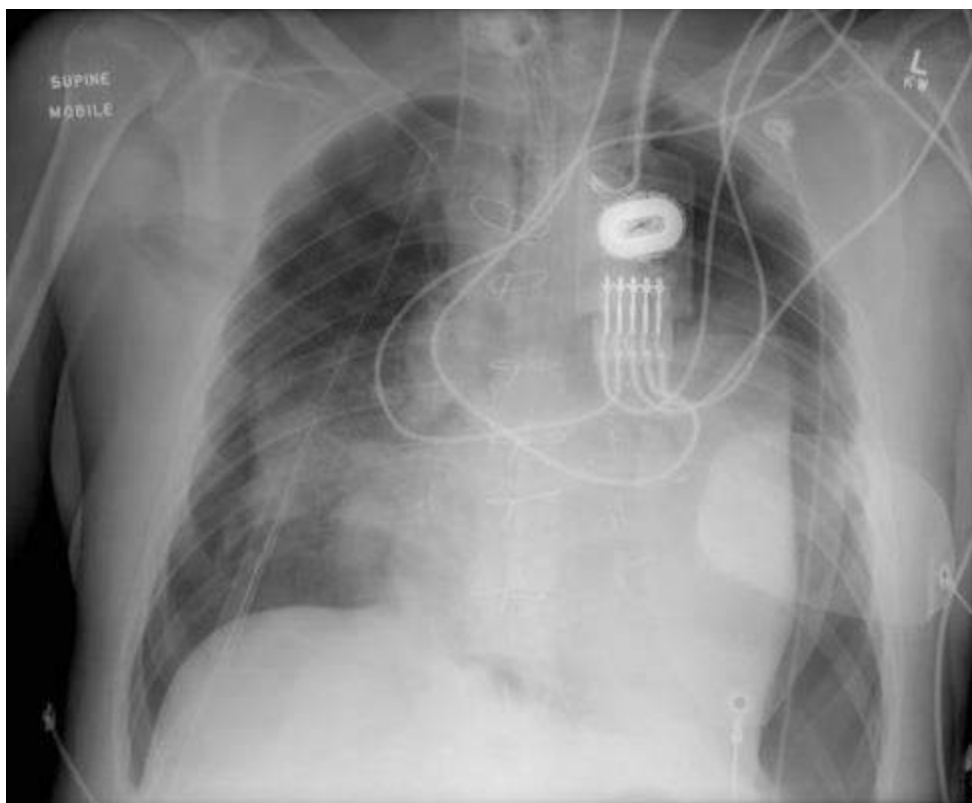
10. There is a left sided anterior pneumothorax (Pink ellipse) as evidenced by hyperlucency over the hemidiaphragm. (It is anterior rather than posterior as it is a supine film and air rises .)
11. There is a right-sided chest drain (Blue arrows) suggesting that a pneumothorax has already been treated on the other side.



Imaging data – Case 12

Question:

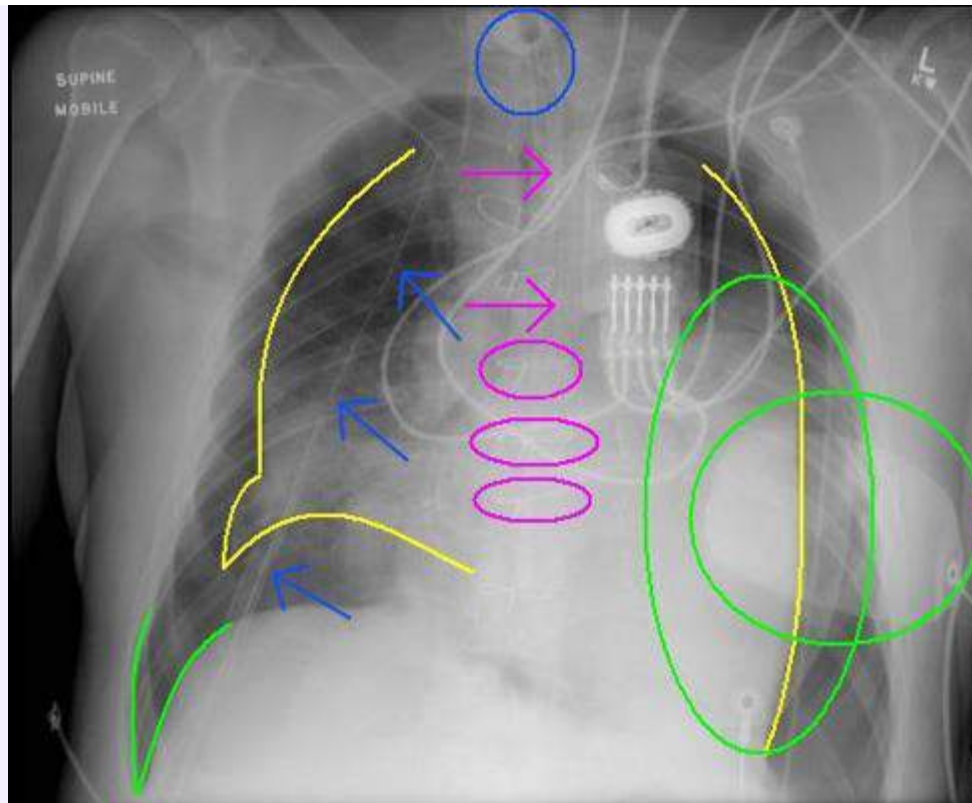
Why was this patient difficult to ventilate?



Answer:

Despite the presence of a right-sided chest drain (Blue arrows) there is a pneumothorax with a prominent deep sulcus sign (Green border) and a visible edge of collapsed lung (Right field yellow border). There is also a pneumothorax on the other side with a collapsed lung (Left field yellow border) somewhat obscured by the overlying defibrillation pads (Green ellipses).

Though not sought for the question, there is also a tracheostomy tube (Blue circle), a gastric tube (Pink arrows), midline sternotomy wires (Pink ellipses) and some ECG wires. These details may be important to consider, depending upon the context and the question asked.



Imaging data – Case 13

Question:

What procedure has this patient had performed? What are the indications for this intervention?



Answer:

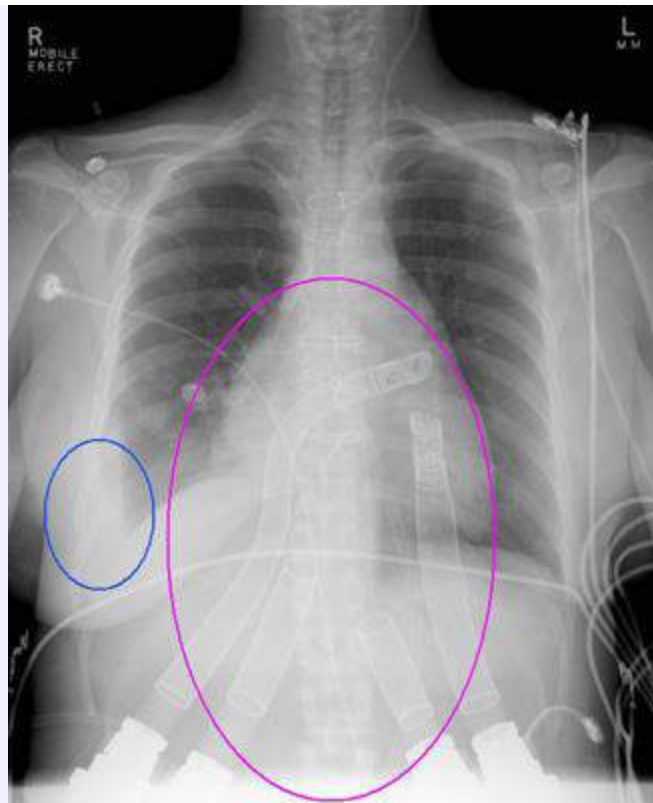
This is a BIVAD (biventricular assist device). Such devices are inserted into patients with severe heart failure most often as a bridge to transplantation.

Indications:

1. Bridge to recovery (e.g. viral myocarditis)
2. Destination therapy in patients unsuitable for a heart transplant (e.g. older patients)

Description

There are four striking tubular opacities ending over the heart (Pink ellipse). There are a number of different models with different appearances of which this is one variant, made by Thoratec™. There is also a right base effusion (Blue ellipse).



Imaging data – Case 14

Question:

What condition is shown in this high-resolution CT lung scan? Name 3 possible causes for this process?



Answer:

Bronchiectasis. There is a cystic, dilated appearance to the bronchial tree with a “tree in bud” appearance.

Causes

A) Congenital:

- Cystic Fibrosis
- immunodeficiency syndromes
- Kartagener's syndrome

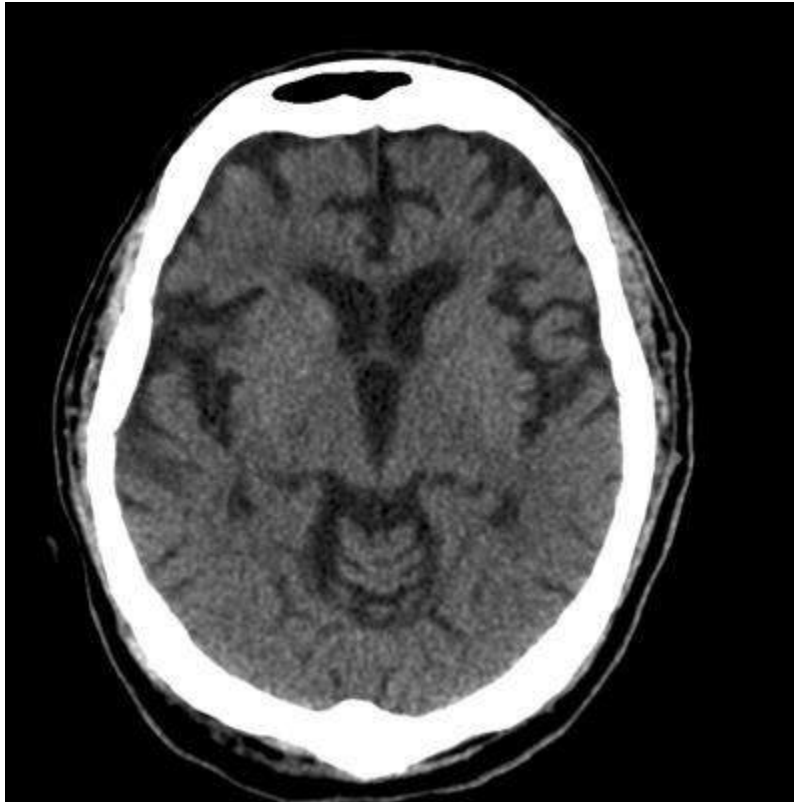
B) Acquired

- necrotizing pneumonias
- aspiration
- toxic gas inhalation

Imaging data – Case 15

Question:

This elderly man was brought into the Emergency Department acutely confused and combative. Can you see an explanation for the acute confusional state on the CT scan?



Answer:

There is a general loss of brain volume with an increase in CSF space volume consistent with hydrocephalus ex vacuo. These changes are classic for cerebral atrophy. The conditions causing this appearance are usually chronic rather than acute (e.g. advanced age, dementias and other neurodegenerative conditions) and therefore do not explain the clinical presentation.

Imaging data – Case 16

Question:

This 38 year old woman presented with headache, photophobia and fever. She was agitated and required intubation and ventilation. No haemorrhage or mass lesion was identified on her CT brain scan. Should she have a lumbar puncture performed?

**Answer:**

The scan is suggestive of cerebral oedema, with homogeneously reduced attenuation of brain tissue, loss of gray-white differentiation and compression of the ventricular system. Lumbar puncture is contraindicated in the presence of suspected raised intracranial pressure. Although the CT scan is not a reliable method of determining this, changes such as those present on this image must not be ignored.

(Other contraindications include uncorrected coagulopathy and local infection. A diagnosis of meningitis can be made clinically, with a causative pathogen identified from testing other bodily fluids/tissues)

Imaging data – Case 17

Question:

What is the most common cause of the principal abnormality seen on this scan?

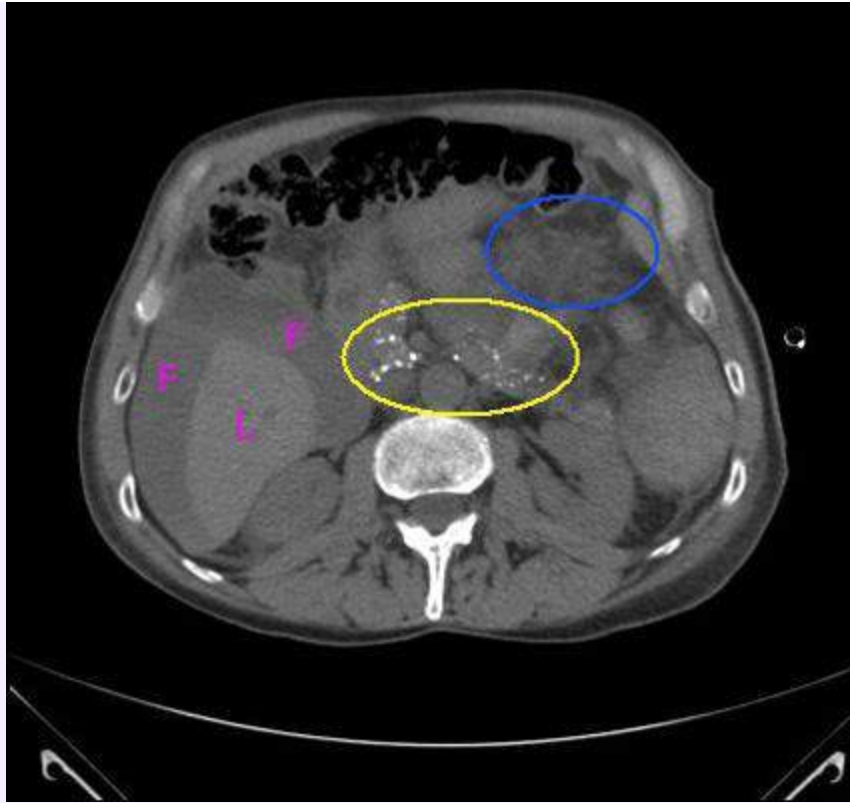


Answer:

Chronic alcoholic pancreatitis

Description

The pancreas is speckled with calcification (Yellow ellipse), which is most commonly associated with chronic alcoholic pancreatitis. There is also free fluid (F) around the liver (L) and diffuse mesenteric fat stranding (Blue ellipse), secondary to inflammation.



Imaging data – Case 18

Question:

What conditions are associated with this finding?

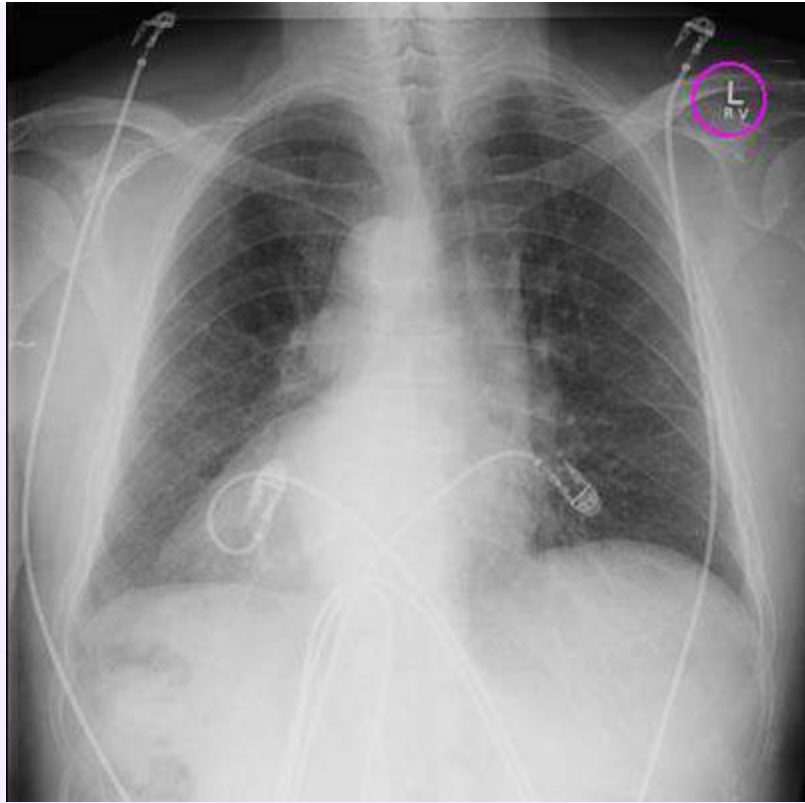


Answer:

Situs inversus totalis and Kartagener's (immotile cilia) syndrome of sinusitis and bronchiectasis.

Description

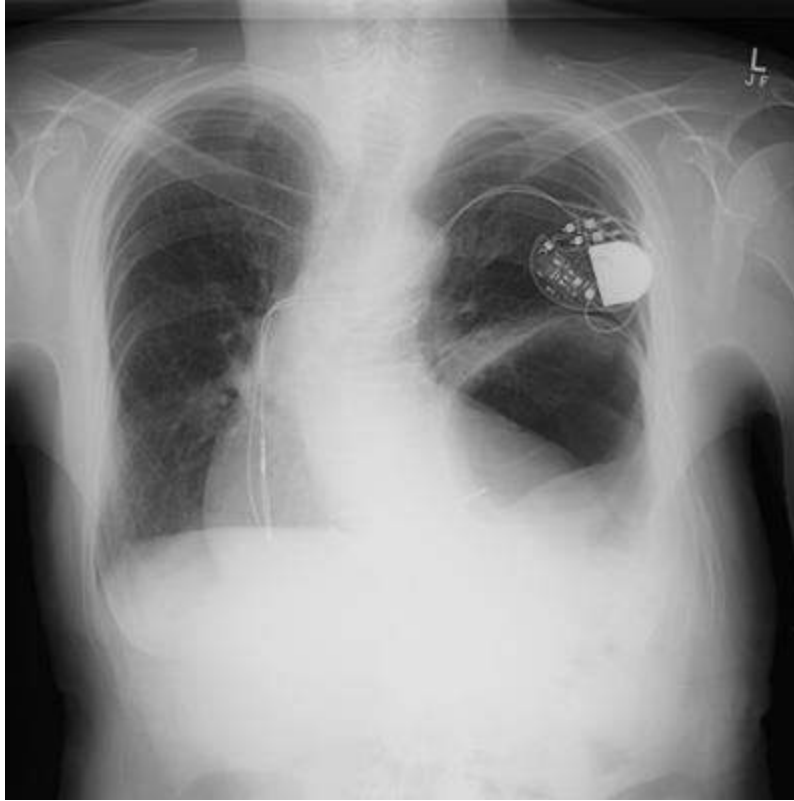
Dextrocardia, as long as the radiographer's label (Pink ellipse) has not been misplaced. A gastric bubble may help, unless there is situs inversus totalis. A transthoracic ECHO would help to confirm the diagnosis.



Imaging data – Case 19

Question:

This elderly patient has a CXR performed while awaiting a repair for a fractured neck of femur. The anaesthetist has requested a post-op HDU bed. Is this request justified based on this CXR?



Answer:

The request is justified.

- Dual lead pacemaker present (Pink arrows) → Cardiac conduction system problems +/- haemodynamic instability potential
- Elevated left hemidiaphragm (Yellow line) with a large gastric bubble beneath it → Phrenic nerve palsy +/- ventilation and/or extubation difficulties +/- aspiration potential
- Small right base pleural effusion (Light blue ellipse) → Possibility of a haemothorax related to the recent trauma and therefore an associated pneumothorax → ventilation and/or extubation difficulties, haemodynamic instability potential
- There are midline sternotomy wires (Dark blue ellipses) → Potential for perioperative myocardial ischaemia
- The cardiac shadow appears enlarged → potential for heart failure

(While the request for the bed may be justified, the final decision regarding her operative and post-operative management will need to be made with regard to her clinical state, co-morbidities and home situation.)



Question:

This patient is currently in theatre, having a laparotomy for management of a ruptured intra-abdominal viscus. The anaesthetist has requested a high dependency unit bed as they anticipate post-operative problems with gas exchange. Outline why you might support the anaesthetist's concern?

**Answer:**

Yes – The patient most likely has Chronic Airways Disease.

There are signs of hyperinflation (hyperexpanded lung fields, flattened diaphragms, more vertical “suspended” appearance to the heart).

The lungs are generally black suggesting a loss of lung tissue consistent with emphysema.

The nodular streaky basal appearances suggest bronchiectasis.

Such patients are at an increased risk of respiratory failure and nosocomial pneumonia after major abdominal surgery.

Imaging data – Case 21

Question:

This elderly patient presented with severe abdominal pain. Their past history included chronic atrial fibrillation, hypertension and hypercholesterolaemia. Name 5 abnormalities. What is the most likely cause?



Answer:

Loops of thickened bowel wall (Pink arrows)

Gas in the bowel wall (pneumatosis intestinalis – Green ellipses)

Mesenteric fat stranding

Free contrast outside the bowel wall (C)

Free gas outside the bowel wall (G)

A unifying diagnosis would be ischaemic bowel with necrosis and perforation secondary to an embolic event complicating their AF.

Imaging data – Case 22

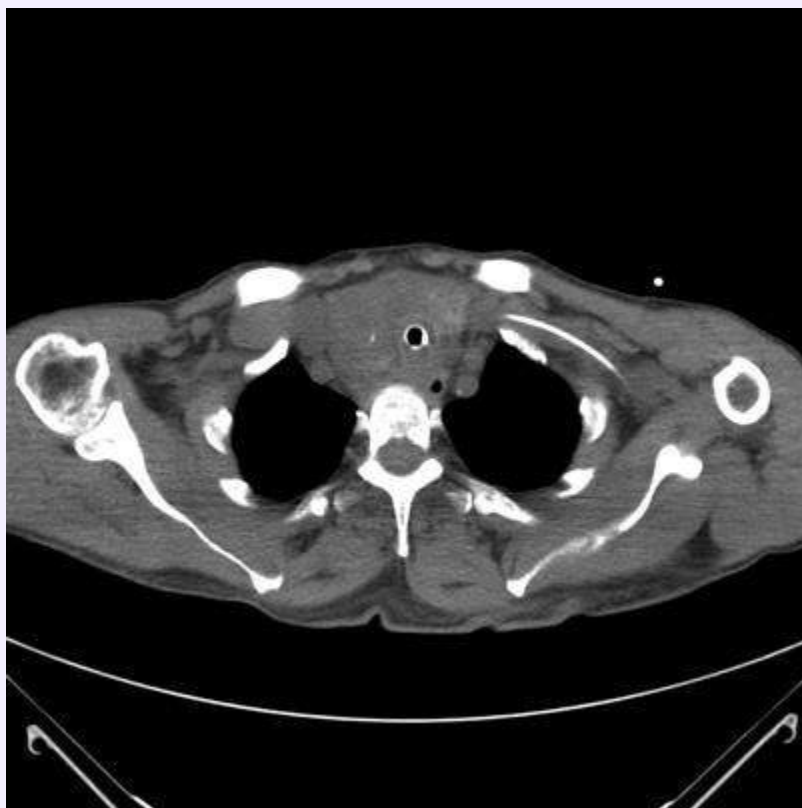
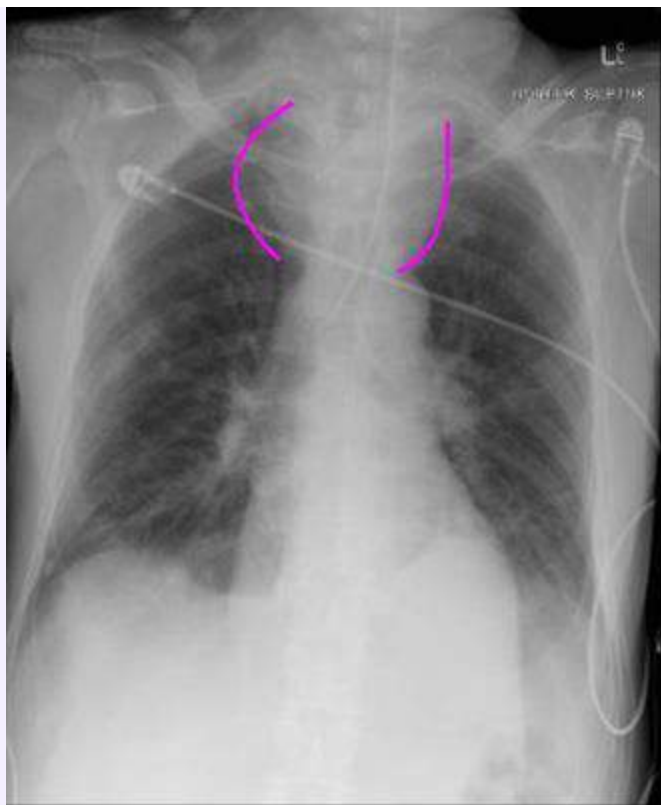
Question:

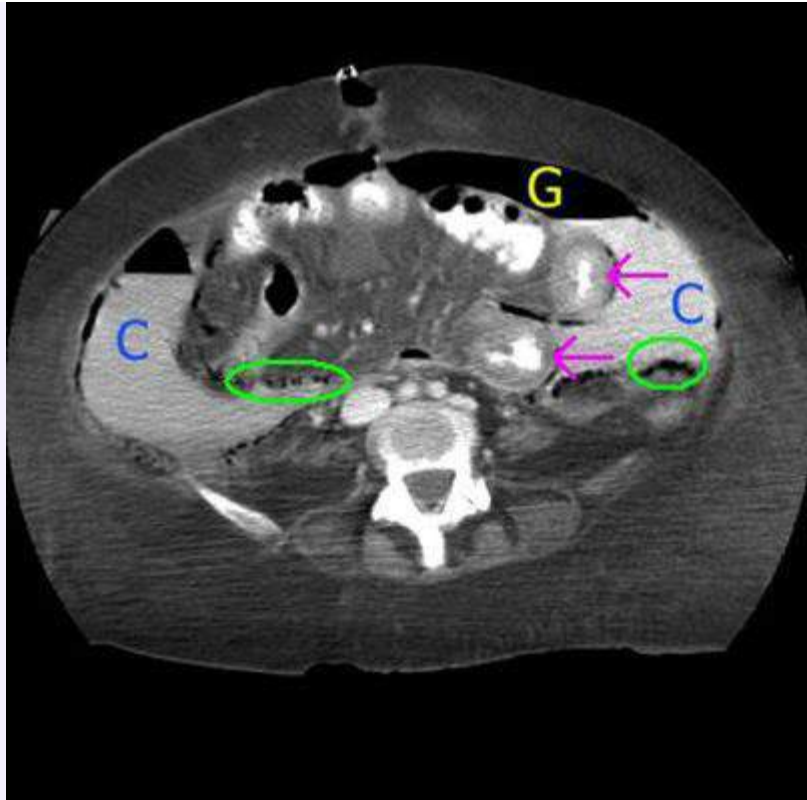
This patient presented with dyspnoea and required intubation for respiratory distress. The intubation was difficult. Identify a cause for these events?

**Answer:**

There is an abnormal upper mediastinal soft tissue opacity (Pink margins). The endotracheal tube appears deviated to the patients left. The lung fields do not show a gross pathology that would explain the dyspnoea. The heart size appears normal. Tracheal compression from a mass lesion is a likely cause of the problems.

The subsequent CT reveals the lesion which was a large retrosternal goiter.





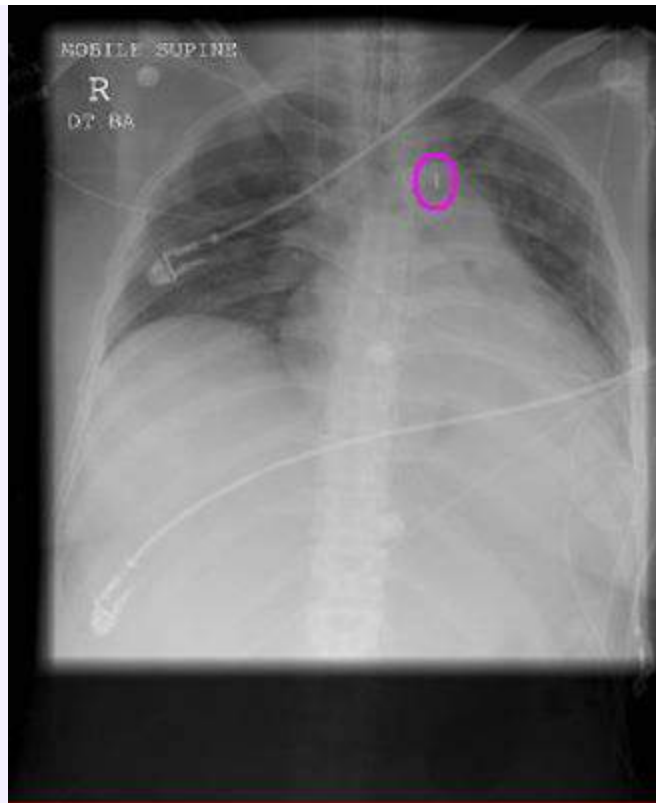
Imaging data – Case 23

Question:

This patient had cardiac surgery earlier today. Are you happy with the intra-aortic balloon pump position and what phase of the cardiac cycle was the film taken in?

**Answer:**

The balloon pump tip has a radio-opaque marker that is located above the first rib anteriorly. Ideally it would be located just above the left main bronchus in the second or third intercostal space anteriorly. If it is too high it may occlude the left subclavian artery causing limb ischaemia. The balloon is not open in this film suggesting the cardiac cycle was in systole at the time the CXR was taken.



Imaging data – Case 24

Question:

What sign is demonstrated on this plain abdominal x-ray taken of a ventilated patient with severe sepsis, too unwell to transport to the CT scanner.



Answer:

Rigler's sign or the "double wall" sign. There is air on both sides of the bowel wall causing a distinct outline of the intestinal loops (Pink arrows). It is a sign of free gas.



Imaging data – Case 25

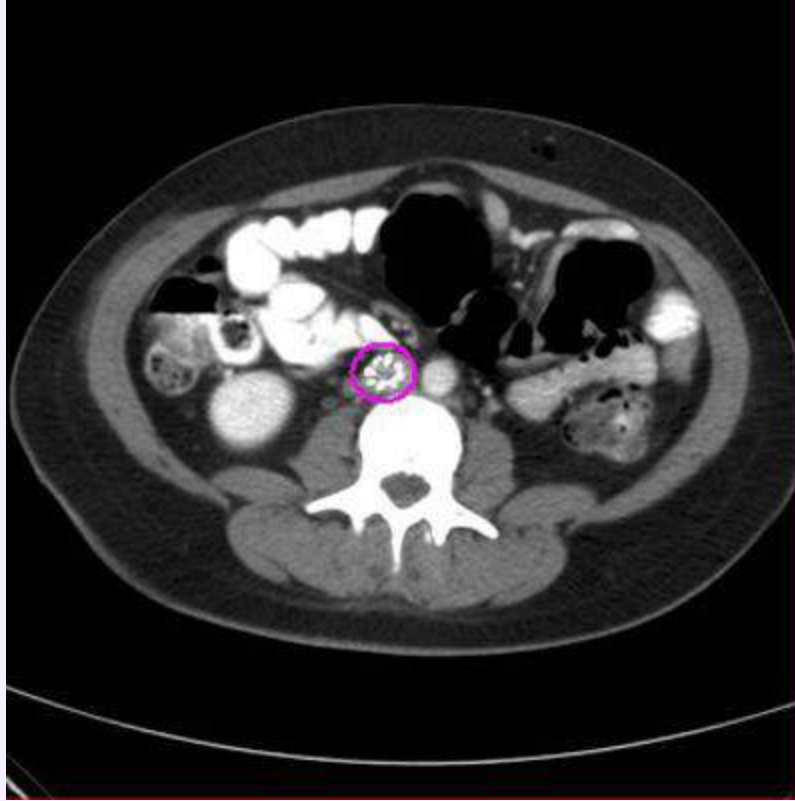
Question:

What procedure has this patient had performed? Why might this have been needed?



Answer:

Insertion of an inferior vena cava filter. This is usually performed to prevent pulmonary embolism in patients at high risk of thromboembolic disease who are unable to be anticoagulated or who have experienced emboli despite therapeutic anticoagulation.



Imaging data – Case 26

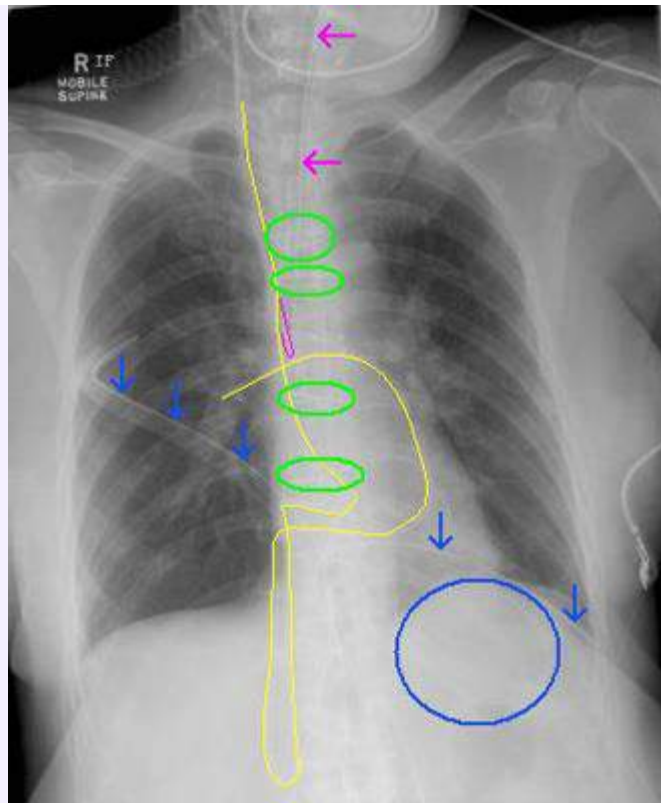
Question:

Comment on the tubes and lines in this chest x-ray of a patient who has just returned from theater after cardiac surgery.



Answer:

- Endotracheal tube – the tip is seen just above the carina and could be withdrawn 1cm (Pink arrows)
- Right sided central venous line – positioned well just above the right atrium (Pink outline)
- Pulmonary artery catheter – the catheter takes a tortuous course below the diaphragm presumably looping in the inferior vena cava before returning to the right atrium then looping into the right main pulmonary artery (Yellow line). The tip is adequately positioned, not crossing the junction of the middle and medial thirds of the ipsilateral lung field.
- Chest drains – several drains including one in each pleural space and a retrosternal drain (Blue arrows)
- Nasogastric tube – the tip is seen curled appropriately below the diaphragm in the stomach (Blue ellipse)
- Sternal wires – lined up in a row (Green ellipses)
- Overlying monitoring leads and ventilation tubing



Imaging data – Case 27

Question:

This patient has had a debridement procedure for dehiscence due to deep sternal wound infection complicating their cardiac surgery.

- What are the risk factors for sternal dehiscence?
- Your resident is also wondering about the lesions in both lower lung fields. What do you think they represent?



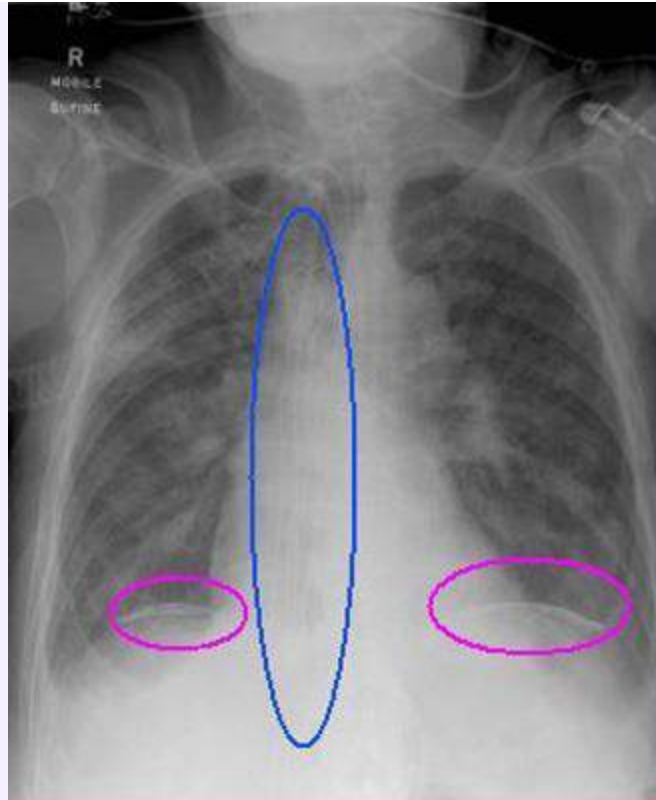
Answer:

a) Sternal dehiscence risk factors:

1. obesity
2. diabetes mellitus
3. immunosuppression
4. excessive coughing
5. internal mammary artery grafts (especially if bilateral)
6. prolonged surgery
7. massive bleeding
8. high dose vasopressors

(The radio-opaque lines within the blue ellipse are the packing material in the wound cavity and indicate that the sternotomy wound has not yet been fully closed.)

b) The bibasal lesions are pleural plaques and suggest prior asbestos exposure.



Imaging data – Case 28

Question:

This is the routine chest x-ray taken 1 hour after completion of a percutaneous tracheostomy. The procedure was difficult with poor bronchoscopic visualization of structures due to excess bloody secretions. What complication are you worried about?

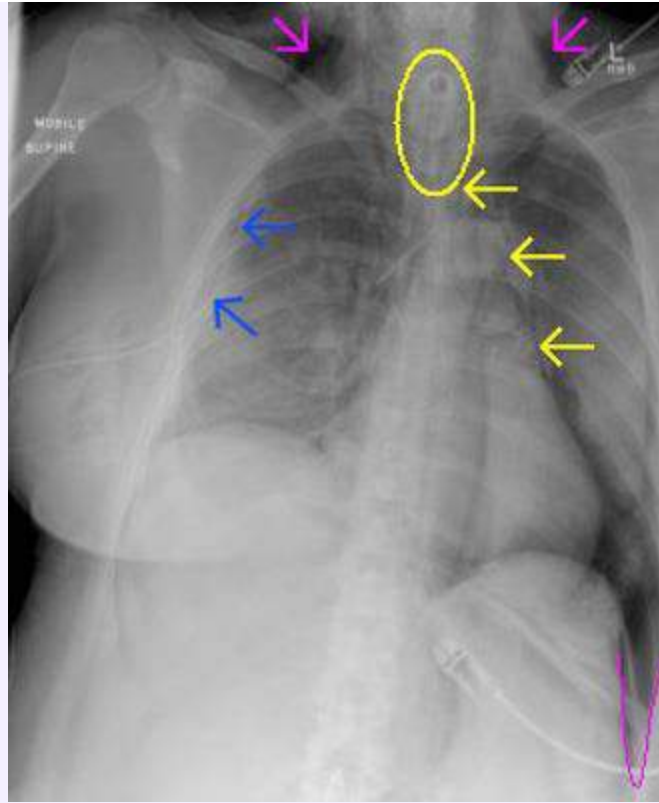


Answer:

A tracheal wall perforation

Description

There is prominent subcutaneous emphysema (Pink arrows) with mediastinal air (Yellow arrows) and a deep sulcus sign (Pink margin) on the left consistent with pleural air. A pneumothorax must be treated, however, the possibility of an airway perforation must be considered. This patient developed increasing subcutaneous emphysema despite having a chest drain inserted. She was reintubated and the stoma explored. A posterior tracheal wall perforation was identified.



Imaging data – Case 29

Question:

This 35 year old, previously well patient presented with haemoptysis and respiratory failure. Acute renal failure rapidly followed. List 4 possible causes for this clinical picture.



Answer:

1. Goodpasture's disease
2. Wegener's granulomatosis
3. Systemic Lupus Erythematosus including Catastrophic Antiphospholipid Syndrome
4. Microscopic Polyarteritis Nodosa

Description

Bilateral diffuse airspace opacification, involving all 4 lung quadrants. There are denser opacities in the right upper and lower zones, which may represent consolidation or increased amounts of alveolar fluid.

There is an endotracheal tube in place, that may need to be advanced a further 1 – 2 cm.

There is a right internal jugular central venous catheter, which, allowing for the rotation of the film, looks to be appropriately positioned.

ECG leads and ventilator tubing are visible on this mobile, supine film

Imaging data – Case 30

Question:

What is the likely cause of the right lung “white-out”?

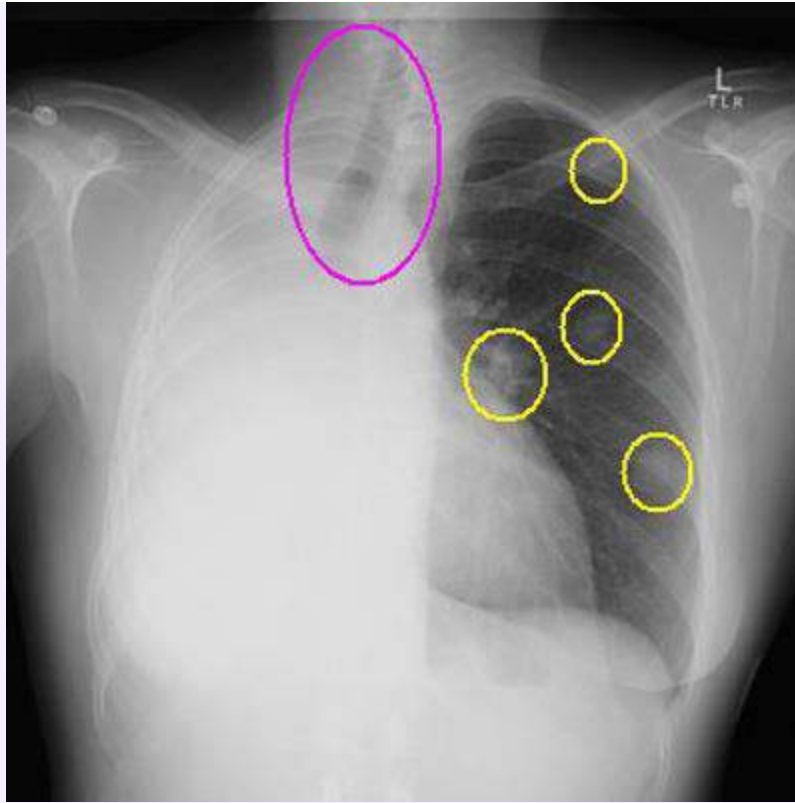


Answer:

Malignant disease; more likely to be metastatic

Description

The trachea (Pink ellipse) is deviated to the side of the lesion consistent with collapse. There is no evidence of previous surgical clips or staples suggesting a pneumonectomy. There are no air bronchograms to indicate consolidation. There is a “cut off” of air in the right main bronchus consistent with an endobronchial obstructive lesion. There are several well-defined opacities in the left lung (Yellow ellipses). Malignant disease would tie all of the appearances together. Look for bone lesions (None on this film.) This patient had a primary lung cancer with metastases.



Imaging data – Case 31

Question:

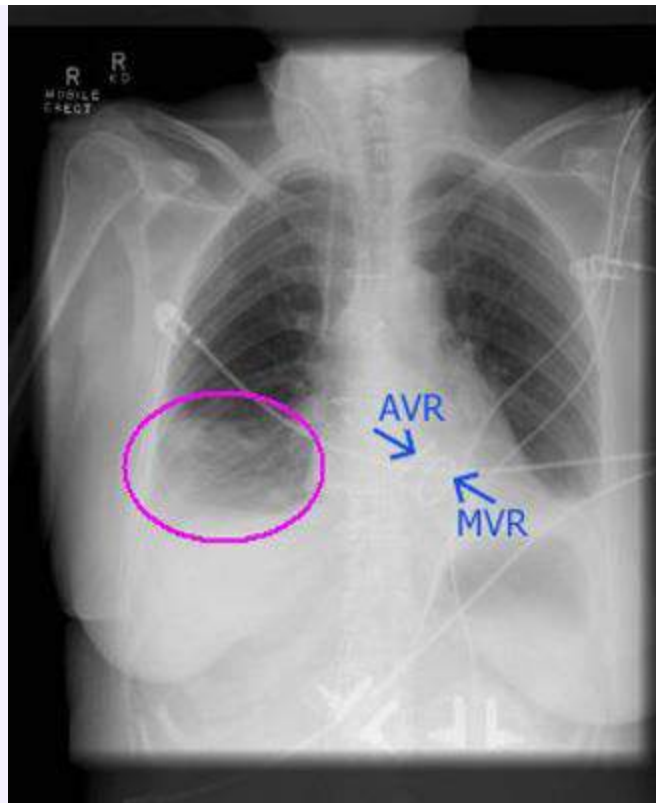
This patient had cardiac surgery three days ago. What operation have they had and what complication is holding up their discharge from ICU?



Answer:

There are two radio-opaque rings consistent with valve surgery. The oblique superiorly located valve with the slit-like appearance is consistent with an aortic valve replacement (AVR = aortic valve replacement). The lower, larger ring, that appears more laterally placed and is seen en-face, is a mitral valve ring (MVR = mitral valve replacement). There are several proposed methods for determining whether a prosthetic valve is likely to be aortic or mitral, based on position, shape, size and perceived direction of flow.

The patient has right lower lobe collapse-consolidation (Pink ellipse). The hemidiaphragm is obscured but the right heart border maintained. The horizontal fissure is shifted downwards.



Imaging data – Case 32

Question:

This patient was admitted with severe community acquired pneumonia. Which lobe(s) are affected?



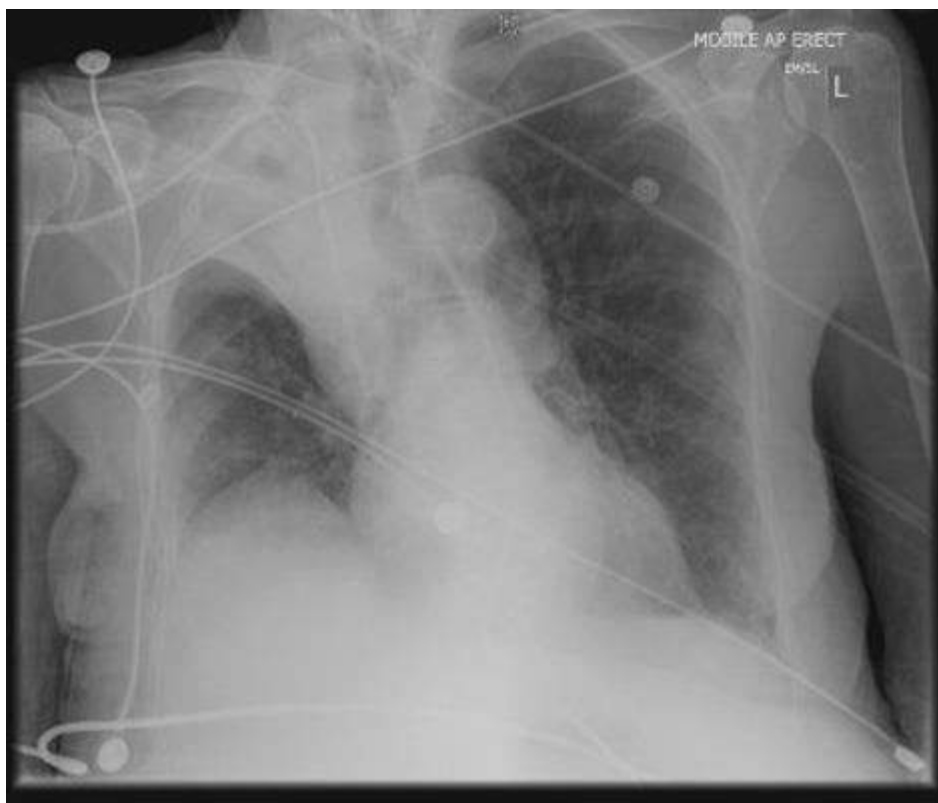
Answer:

Right middle (the right heart border is obscured) and lower lobes (the hemidiaphragm is obscured).

Imaging data – Case 33

Question:

This patient was admitted to the ward 4 days ago with a new productive cough. What is the likely cause of the patient's deterioration in gas exchange and new fever over the last 12 hours?

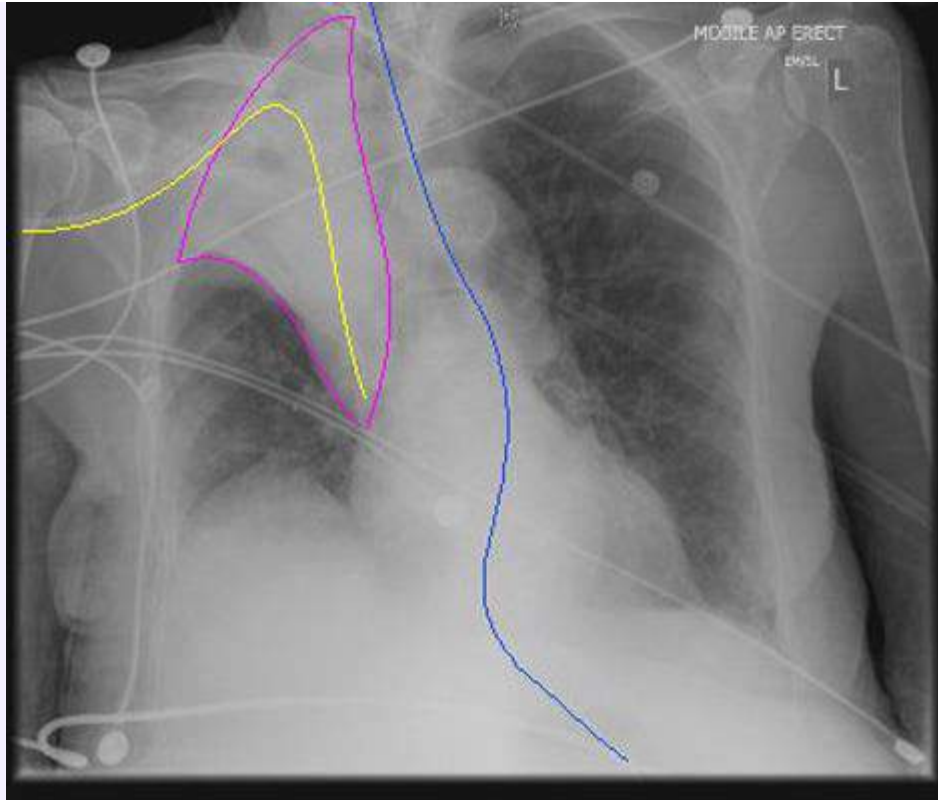


Answer:

Right upper lobe pneumonia

Description

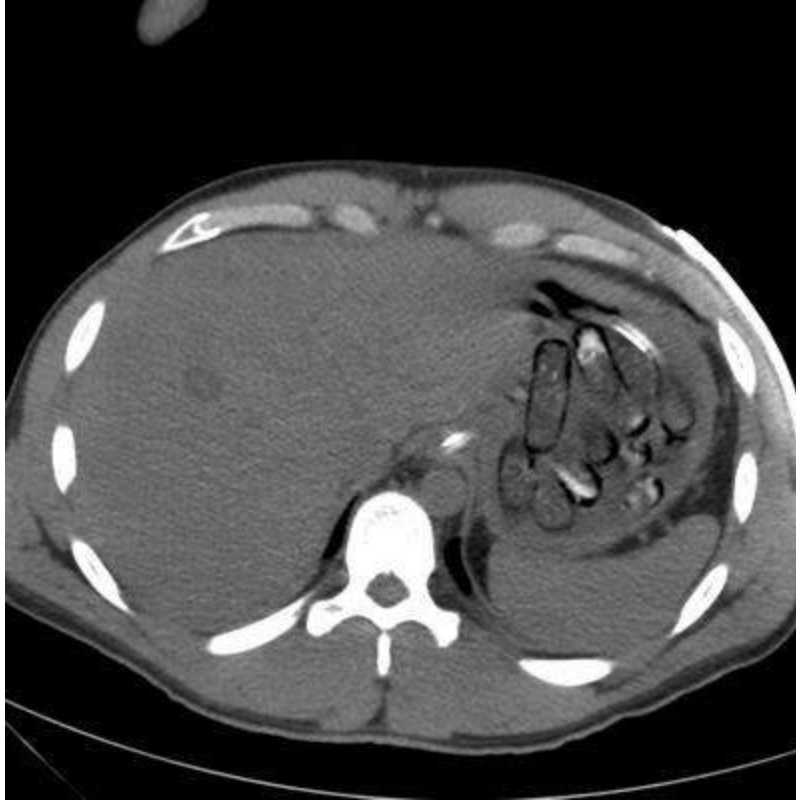
Right upper lobe pneumonia would explain the deterioration in gas exchange and fever. There is opacification of the right upper lobe (Pink outline) with air bronchograms and significant loss of volume as the horizontal fissure is displaced cephalad. If the central venous catheter (Yellow line) had been in place since admission it could be the source of fever as such lines are at high risk of causing bacteraemia when left more than 72 hours. The presence of a gastric tube (Blue line) may also be a source of pulmonary infection, in the form of aspiration pneumonitis.



Imaging data – Case 34

Question:

This young man experienced a sudden cardiac arrest at the airport having just flown in from Thailand. A CT abdomen was performed as abnormal opacities were noted on his supine chest x-ray performed after intubation. What is the likely cause of the cardiac arrest?

**Answer:**

"Body packing" of illicit drugs

Description

There are multiple well-circumscribed foreign bodies located in the stomach (Yellow ellipse). Further history from the patient's friend revealed that they were tightly packed bundles of cocaine. Leakage and rapid absorption of drug resulted in the arrest. This is a recognised complication of being a "body packer" or "drug mule".



Imaging data – Case 35

Question:

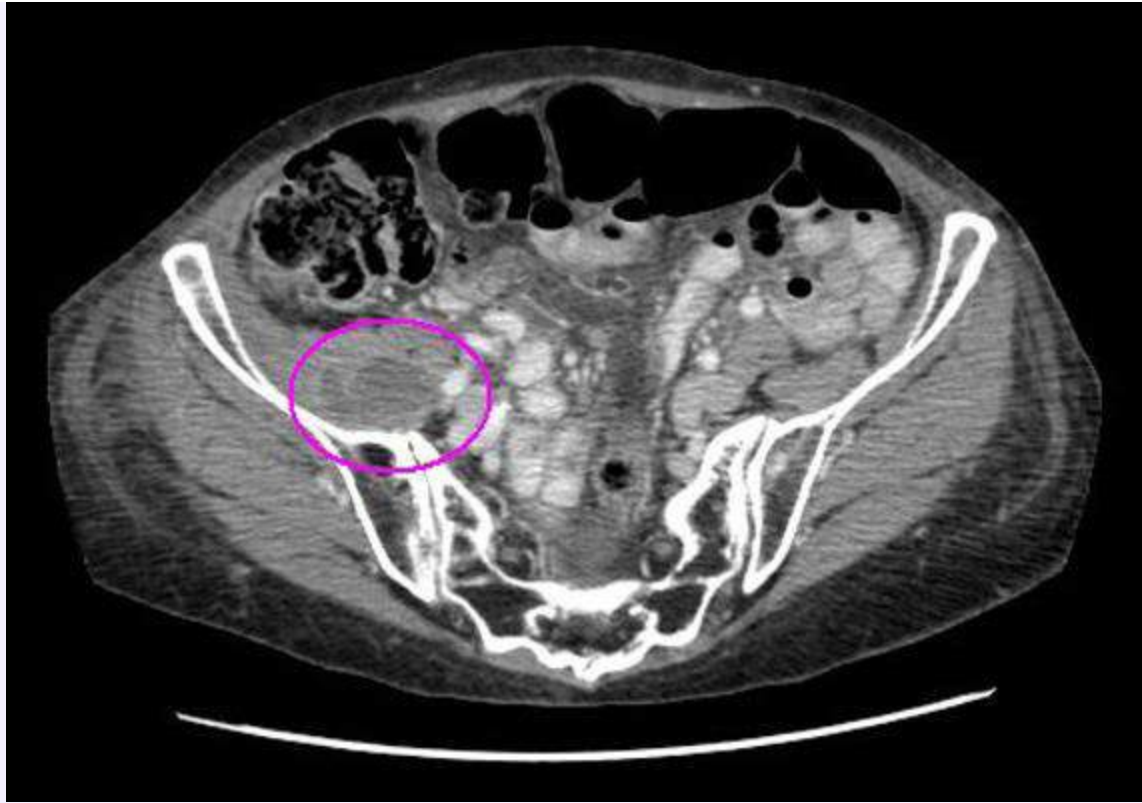
This elderly patient complained of severe right hip pain and deteriorated on the Orthopaedic ward with septic shock requiring intubation and ventilation. A CT of her abdomen, pelvis and right hip was performed with contrast. What is the likely cause of this clinical picture and what other investigations would you consider performing?



Answer:

There is a right iliopsoas muscle abscess.

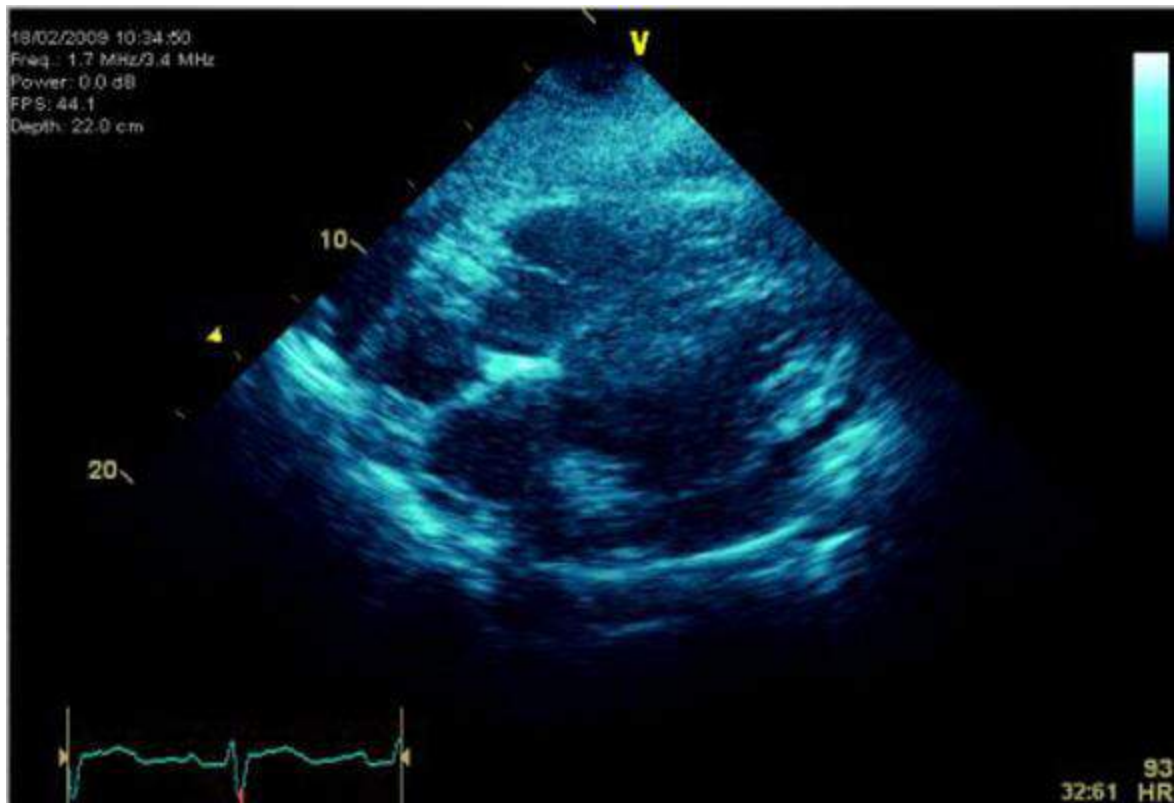
A transoesophageal echocardiogram and imaging of the spine (e.g. MRI) should be considered. A source of the infection should also be sought including cutaneous lesions and wounds and foreign material such as vascular access catheters and surgically implanted devices. (The most common infective cause is *Staphylococcus aureus*, which has a predilection for causing infection at multiple classical sites including the spine and heart valves.)



Imaging data – Case 36

Question:

A 69 year old patient has been started on Continuous Renal Replacement Therapy (Mode = CVVHDF) following an admission through the emergency department with acute on chronic renal failure. The patient has been hypotensive and tachycardic since admission, despite several intravenous fluid challenges. There is no fever and the patient is mildly confused. A transthoracic ECHO is performed to try to clarify the cause of the hypotension. A still image of the subcostal view is shown below. What pathology is demonstrated and list 3 possible causes in this patient?



Answer:

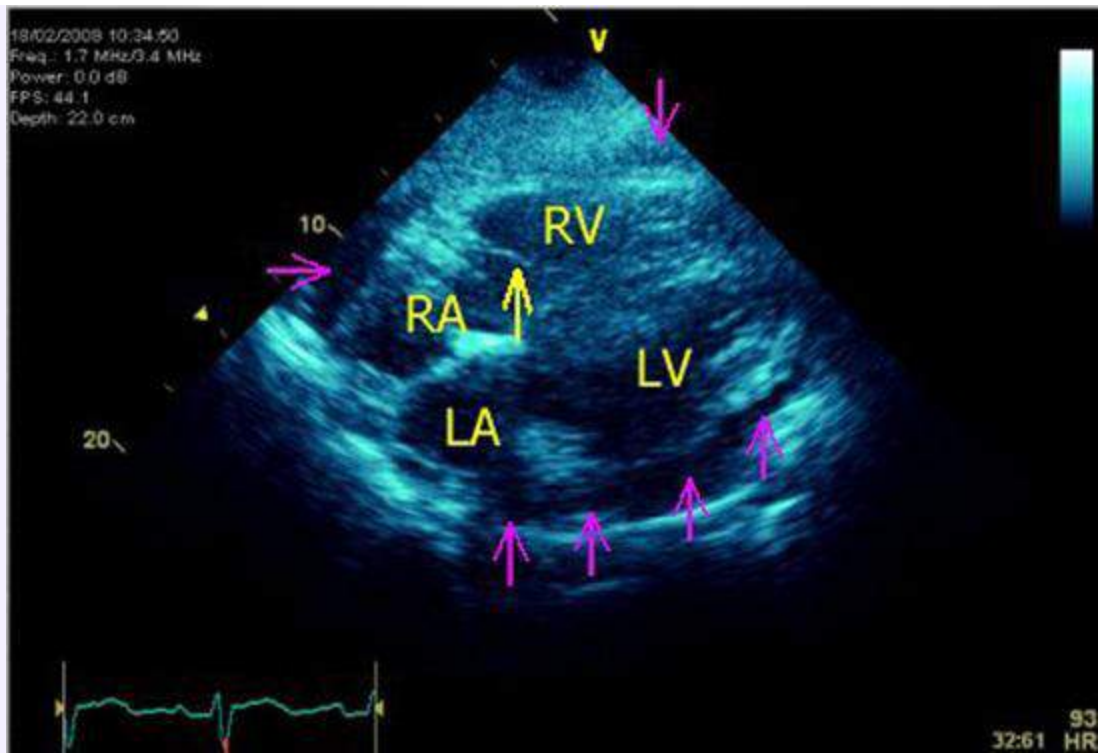
Pathology = Moderate size pericardial effusion

Causes:

- Uraemic pericarditis
- Nephrotic syndrome
- Haemorrhagic pericarditis

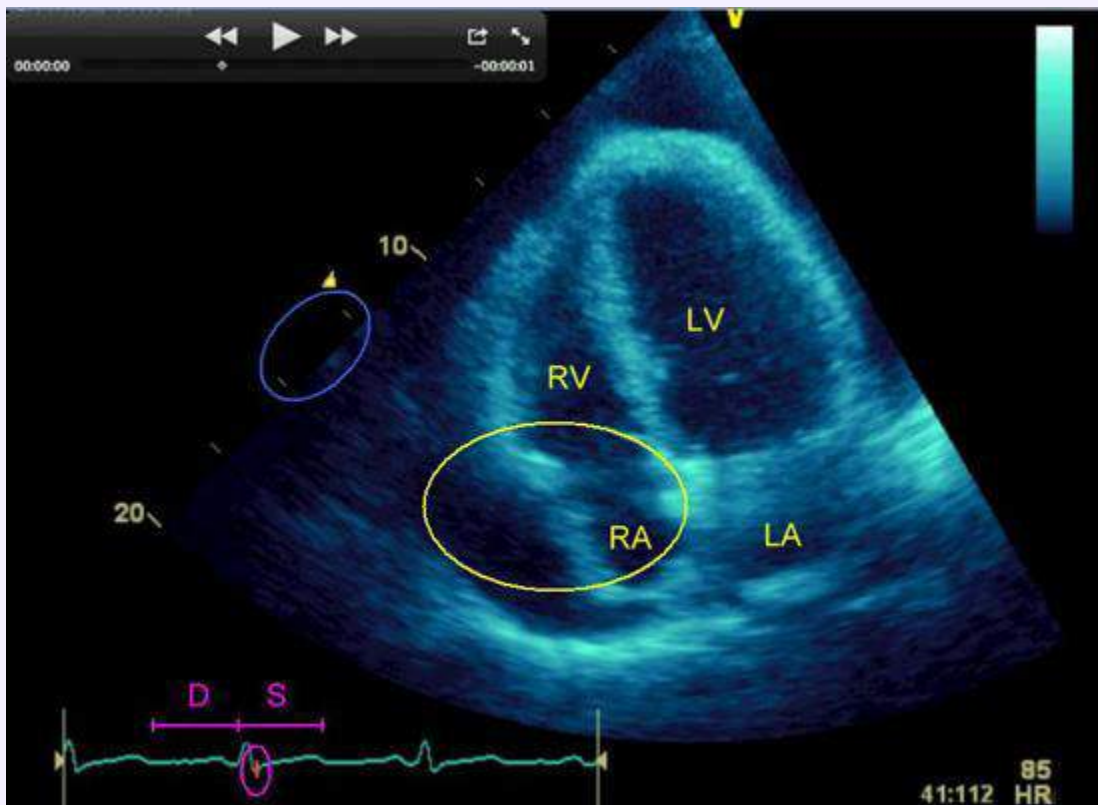
Rationale:

The still image shows a typical subcostal view the heart, with the right ventricle (Image A - RV) closest to the probe, separated by the tricuspid valve from the right atrium (Image A - RA) to the left of the image. The yellow arrow in Image A is pointing to the moderator band that runs across the chamber of the right ventricle. The heart is surrounded by a rim of free fluid; the pericardial effusion (Image A - Pink arrows).



(A)

SC pericardial effusion - Marked



(B)

RA tamponade – Marked

Additionally, any time a pericardial effusion is identified, it should be quantified and evidence of tamponade sought.

Effusion depth

< 10mm: Mild

10 – 20mm: Moderate

>20mm: Large

Use the scale to the left of the main image to gauge the depth of the effusion (Image B - Blue ellipse)

Tamponade severity

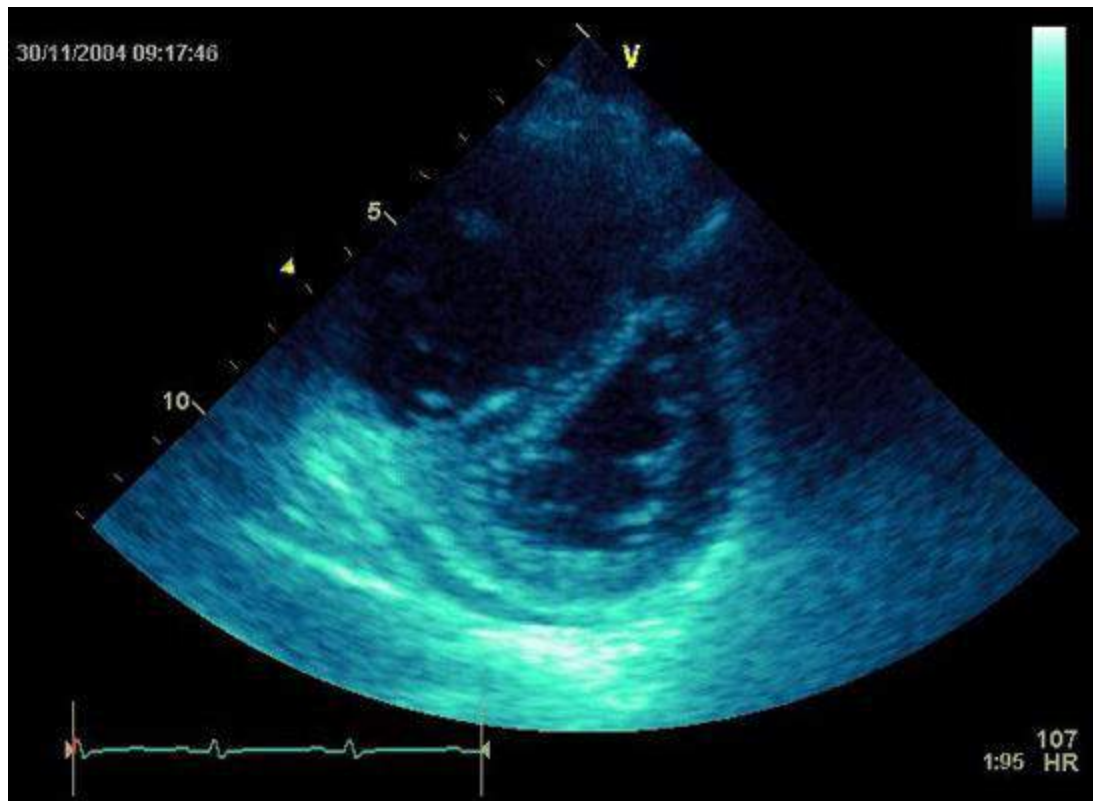
- None
- Moderate – Early systolic collapse of the RA free wall (Image B – Yellow ellipse). Some authorities argue that the low RA chamber pressures make free wall collapse so likely that it cannot be used to grade the severity of tamponade.
- Life threatening – Collapse of the right ventricular free wall

Pericardial tamponade is a clinical diagnosis but these images are highly supportive. Remember, the size of the effusion does not alone determine the likelihood of tamponade; the rate of accumulation is more important. Use the red marker (Image B – Pink ellipse) on the ECG rhythm strip on the screen to determine where in the cardiac cycle the image has been captured (Image B: D = diastole, S = systole).

Imaging data – Case 37

Question:

A 43 year old lady, who has been mechanically ventilated in the ICU for the past three weeks because of Guillain-Barré syndrome, becomes suddenly hypotensive and tachycardic. Her SpO₂ falls to 78% and she becomes drowsy. A bedside transthoracic ECHO is performed and a captured image is displayed below. The sonographer informs you that the V_{TR} is 4.9 m/Sec and the estimated RAP is approximately 10mmHg.



- a) What pathology would you consider based upon the results of the transthoracic ECHO?
- b) How do the results influence your management of this patient?

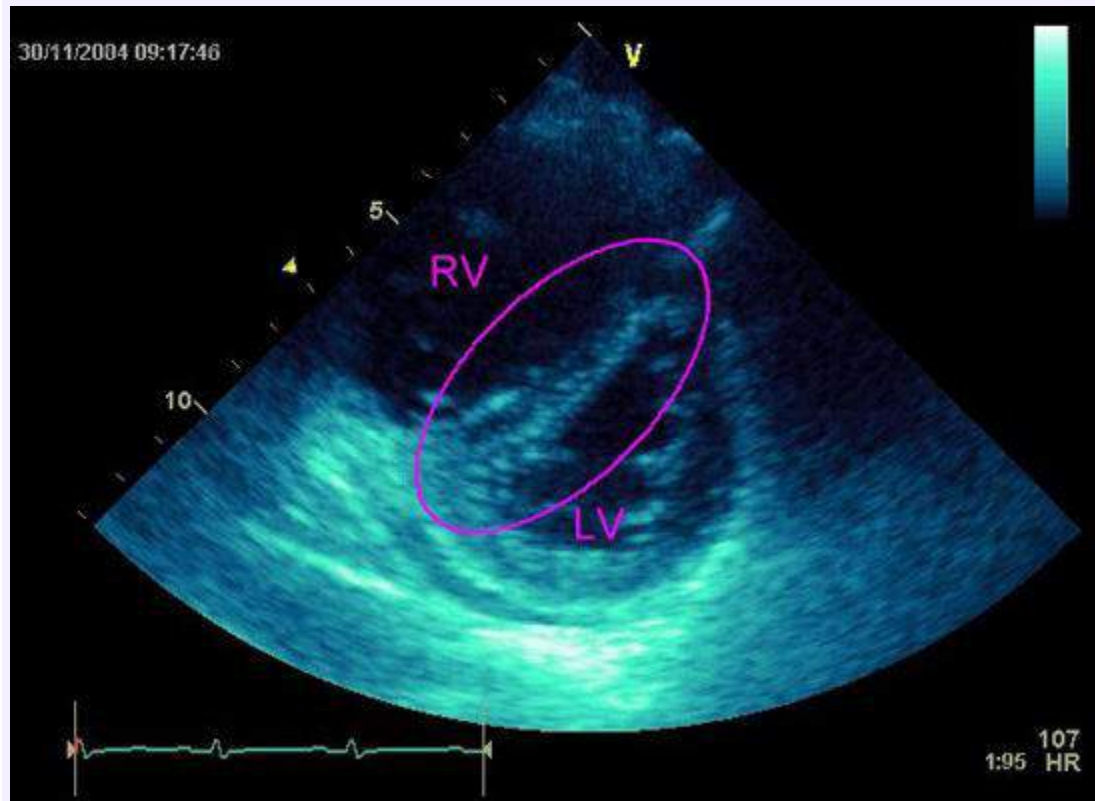
Answer:

- a) Acute massive pulmonary embolism
- b) In this patient's context, emergency thrombolysis

Rationale:

The still image shows a significantly dilated right ventricle at the transition point between end-diastole and the start of systole when ventricular volume is greatest. The interventricular septum is normally convex into the right ventricle, due to the structure of the heart and the higher LV luminal pressures. In this image, however, it is flattened (Pink ellipse), so that the usually circular left ventricle is now D-shaped. This feature strongly suggests elevated RV pressures. The sonographer's $4V_{TR}$ result confirms the suspicion, as the modified Bernoulli equation ($4V_{TR}^2$) is used to estimate the systolic pulmonary artery pressure, as long as the pulmonary valve is normal. In this case $[4 \times 5^2] + RA$ pressure yields an estimated systolic pulmonary artery pressure of 110mmHg. A value above 30mmHg is raised and above 70mmHg is severe. However, you don't need this number to make the management decision in this case, as it

would be reasonable to thrombolyse an acutely hypotensive, tachycardic, hypoxic patient with PE risk factors (in this case prolonged immobility) and the described 2D ECHO appearance of a D-shaped septum.



Imaging data – Case 38

Question:

A 31 year old is brought to the emergency department following a high speed motor vehicle collision. He has a patent airway, equal breath sounds and an SpO₂ of 99%. His heart rate is 126bpm and his blood pressure is 94/57mmHg. He is alert but moderately combative. During the initial assessment a FAST scan is performed. Please interpret the abdominal views and state their influence on this patient's management.

A



B



C

Answer:

The abdominal views of this FAST scan show a Morrison's pouch view (Image A), a lienorenal view (Image B) and a transverse suprapubic view (Image C). There is a volume of free fluid in the lienorenal angle of image B. This is most likely to represent blood in this context and might originate from a splenic or renal injury. There may be a free fluid volume in Morrison's pouch, in image A, but it is obscured by the shadow artefact, which is likely to originate from the probe array as it is present in the same position on all three images. There is no evidence of a free fluid volume on the suprapubic view (image C), though the gain is a bit high.

The presence of a free fluid volume on a FAST scan in a haemodynamically unstable trauma patient is an indication for urgent transport to theatre for damage control surgery.

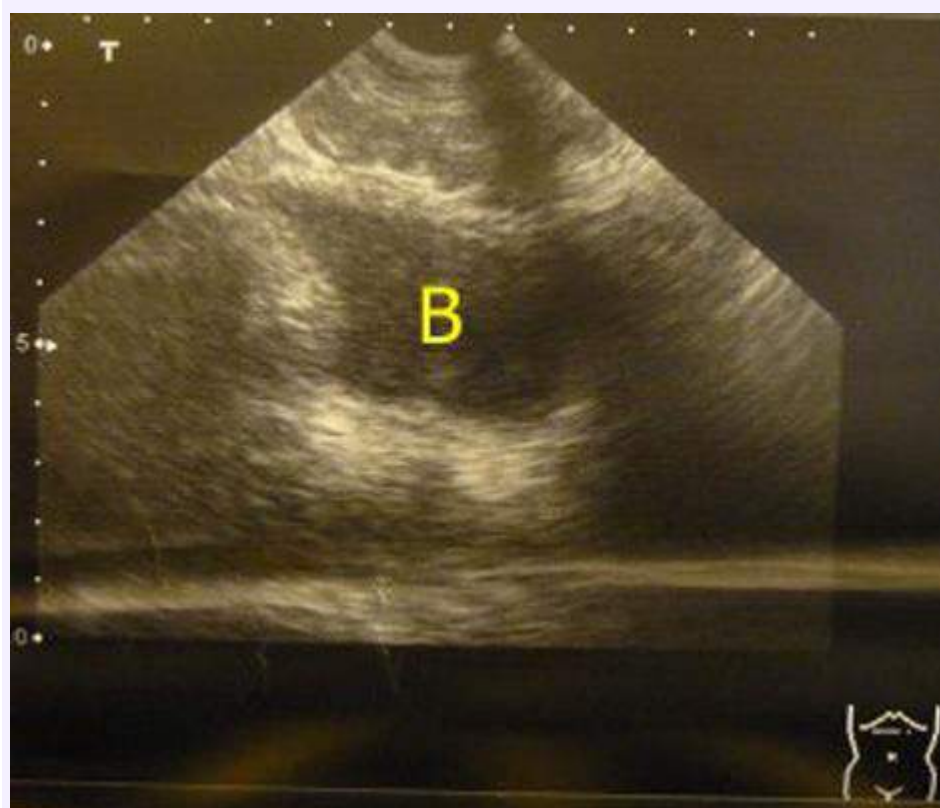
Rationale:



A



B



C

Morrison's indeterminate - Marked.jpg, Lienorenal pos – Marked.jpg and Suprapubic neg - Marked

Image A: Morrison's pouch view - L = Liver, K = Kidney, Yellow circle = possible fluid volume obscured by shadow artefact.

Image B: Lienorenal angle view – S = Spleen, K = Kidney, Yellow circle = free fluid volume

Image C: Transverse suprapubic view - B = Bladder. The walls of the bladder have a high signal suggesting that the gain is too high. This may obscure a small free fluid volume.

Monitoring data case

Monitoring data is a frequent exam item. It is popular with examiners, who see it as a marker of hands-on clinical experience. Some of the favourite monitoring data that turns up in exams are ventilator waveforms, end tidal CO₂ (EtCO₂) waveforms and intra-aortic balloon pump waveforms, but any piece of ICU equipment that displays either numerical (e.g. PA catheter, FloTrac®) or graphical (e.g. ventilator scalars and loops, ICP monitor) data may be presented.

Questions that centre around commonly used equipment often come in several parts that query a candidate's understanding of its key components and their underlying principles of action, how the equipment is placed or set up, interpretation of the data displayed and potential hazards of its use. Where the use of a piece of equipment is controversial, the literature that highlights the pros and cons of its use may be questioned; e.g. the PA catheter, Bispectral index monitor.

Tips for monitoring data questions

1. Know the equipment in your department. Then go and find departments that use other equipment and spend some time with them.
2. Have a structure for approaching equipment questions.
3. In the exam, be wary of being rigidly critical of a given piece of equipment, as there are zealots and critics alike amongst the examiner cohort. However, have an opinion and be able to justify it.
4. Read through your department's equipment protocols and troubleshooting guidelines, as these are often good sources of examination questions. The nurse educators in your department and the manufacturer's website may have additional information.

You should try and memorise some of the more common reference ranges for monitoring data, mostly as it saves time when attempting the answer. However, it is recognised that hospitals often have varying reference ranges, based on the equipment calibration, so "normal" values are usually provided in exams. A set of reference ranges is provided for the monitoring values used in the following questions. You can access them by clicking on the Reference ranges link on the upper right hand side of the page

Monitoring data – Case 1

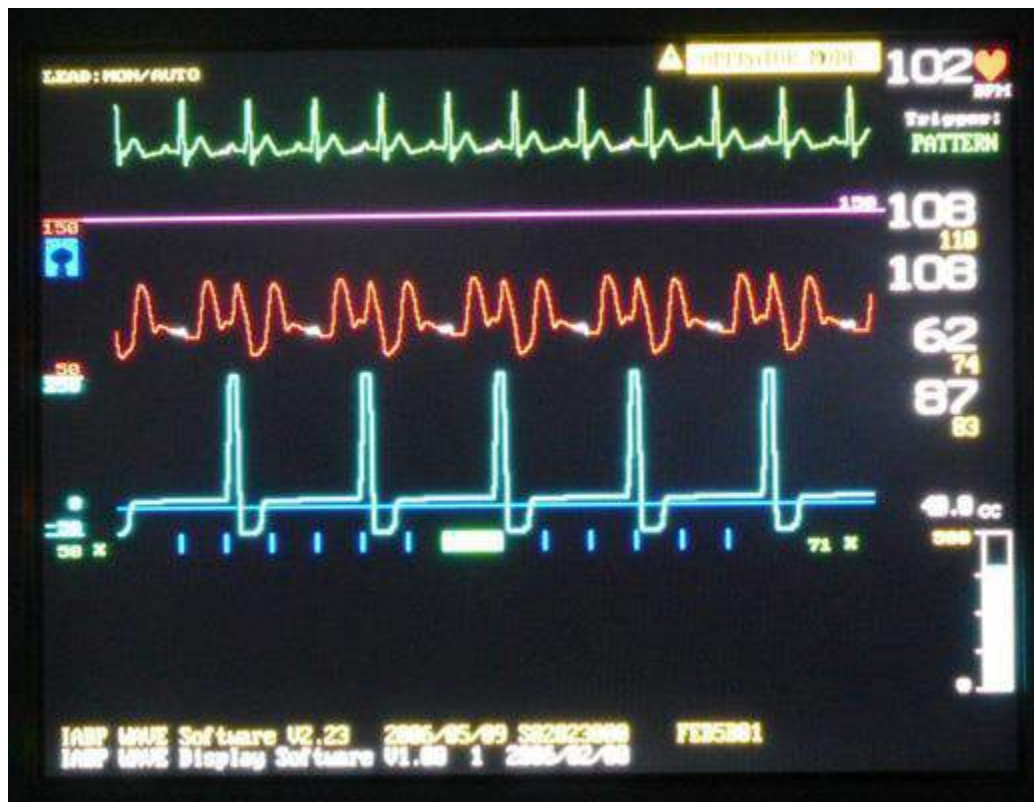
Question:

a) A 68 year old gentleman has been admitted to your ICU following an acute myocardial infarct. He has had a coronary angiogram, which demonstrated diffuse left anterior descending and left circumflex disease that was not amenable to stenting. He required invasive ventilation for worsening pulmonary oedema. Overnight he has become progressively more hypotensive and a pulmonary artery catheter was inserted by the ICU registrar. On the morning ward round, the patient is on dobutamine at 7mcg/kg/min, noradrenalin (norepinephrine) 0.08mcg/kg/min and has

received 3250mls of intravenous crystalloid. His heart rate is 118bpm sinus, with a blood pressure of 78/52mmHg. His nurse hands you his latest PA catheter study. What intervention would you instruct your registrar to perform next?

HR 122 bpm	C.O. 2.5 L/min
MAP 55 mmHg	C.I. 1.38 L/min/m ²
CVP 18 mmHg	SVR 1684 dyne-s/cm ⁵
RV pres 31/10 mmHg	SVRI 2744 dyne-s/cm ⁵ /m ²
PA pres 32/17 mmHg	PVR 160 dyne-s/cm ⁵
mPAP 22 mmHg	PVRI 289 dyne-s/cm ⁵ /m ²
PAoP 17 mmHg	SV 22 ml

b) You check on the patient's progress an hour later and when you interrogate the IABP at 2:1, you notice the following on the IABP monitor. What changes would you make?



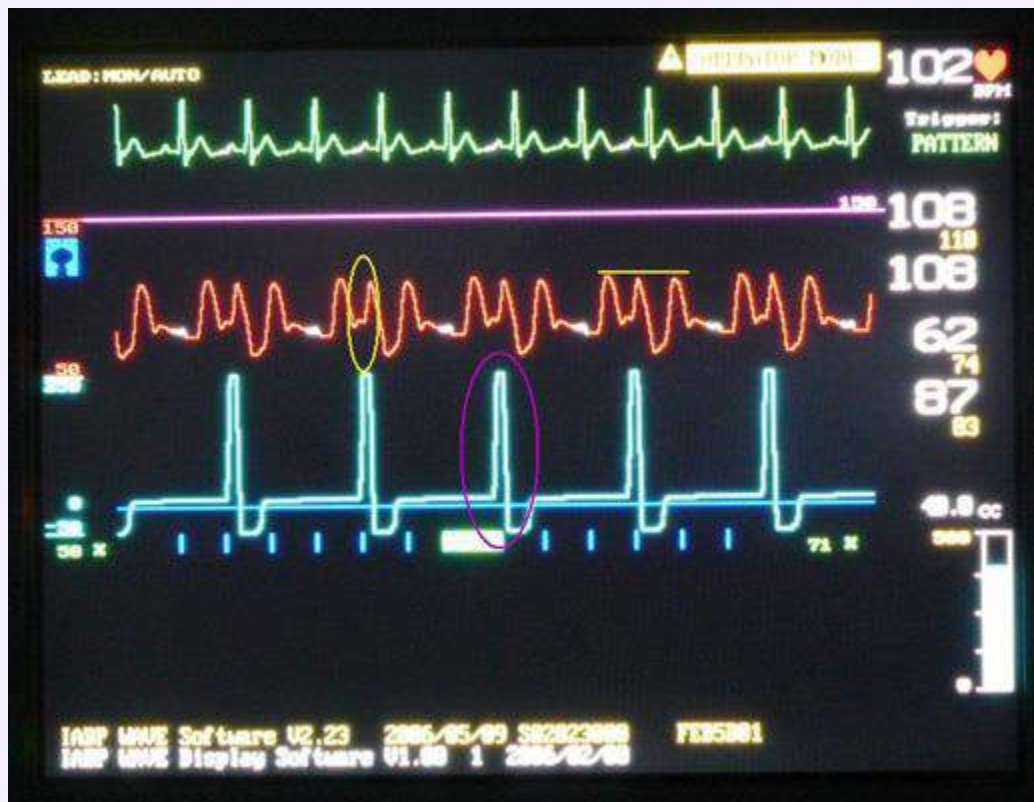
Answer:

a) Commencement of an intra-aortic balloon pump.

Rationale

PAC data suggests cardiogenic shock, with a low MAP, SV, CI and CO, high CVP, PaoP and SVR/SVRI. The patient is already volume loaded (raised CVP) and increasing the noradrenalin (norepinephrine) or dobutamine is unlikely to add benefit, as the SVR/SVRI and HR are respectively already elevated. Therefore, mechanical assistance, in the form of an IABP, would be justifiable.

b) Set an earlier balloon inflation to match the onset of inflation to the upstroke of the diastolic notch.



Description

Diagnosis = Late balloon inflation

Visible dirotic notch with a delay to the onset of balloon inflation (Yellow ellipse)

Assisted systolic pressure peak approaching the same height as the unassisted systolic pressure peak (Horizontal yellow line). Additionally, the augmented diastolic peak has dropped to the same height as the unassisted systolic pressure peak.

Narrow balloon inflation waveform (Purple ellipse).

Monitoring data – Case 2

Question:

A 73 year old patient has returned from an on-pump three vessel CABG 2 hours ago. She has remained hypotensive since her return. She has a background of type 2 diabetes mellitus, hypertension and mild emphysema. She has received 2 litres of colloid since her return and is on 0.25mcg/kg/min of noradrenalin (norepinephrine). You are shown her latest PA catheter data. What aspects would you check on assessing the patient for the cause of her persistent hypotension and how would you respond to each?

HR 115 bpm	C.O. 3.2 L/min
MAP 52 mmHg	C.I. 2.0 L/min/m ²
CVP 5 mmHg	SVR 1880 dyne-s/cm ⁵
RV pres 16/2 mmHg	SVRI 2805dyne-s/cm ⁵ /m ²
PA pres 16/5mmHg	PVR 20-100dyne-s/cm ⁵
mPAP 8 mmHg	PVRI 180dyne-s/cm ⁵ /m ²
PAoP 4 mmHg	SV 31 ml

Answer:

- Check anaesthetic record for mismatch of volumes lost and replaced.
- Physical examination for evidence of peripheral hypoperfusion
- Mediastinal drain output rate – If > 200ml/hr then advocate for return to theatre if no significant coagulopathy to be corrected.
- Identify and correct any coagulopathy; e.g.
- aPTT (Heparin for CPB) – Protamine
- low platelets (CPB mediated destruction) – pooled platelets

- hypothermia (CPB and cardioplegia) – passive and active warming
- acidosis – identify and correct cause
- use of aspirin or clopidogrel within 5 days of surgery – pooled platelets
- significant uraemia due to ARF – dialysis.
- Check latest Hb trend for acute blood loss – Replace to > 7.0 g/dL (higher if ongoing bleeding or active ischaemic cardiac features) and differentiate surgical from coagulopathic bleeding

Rationale:

This patient's PA catheter data suggests hypovolaemia, given the tachycardia, low CVP, MAP, PaOP, C.O. and C.I. with a raised SVR and SVRI. Postoperatively, the most likely causes of hypovolaemia are bleeding and inadequate volume replacement. Persistent anaesthetic effect is less likely given the length of time that has elapsed and the SVR and SVRI would be more likely to be low, due to the vasodilatory effect of the agents used

Monitoring data – Case 3

Question:

Your registrar calls you in the middle of the night for advice regarding a 75 year old patient who returned from an aortic valve replacement and 2 vessel bypass procedure late in the evening. The patient has a background history of hyperlipidaemia, type 2 diabetes mellitus and rheumatoid arthritis. The patient has become increasingly hypotensive over the past 4 hours, having initially had a good blood pressure on 0.08mcg/kg/min of noradrenalin (norepinephrine) and an electively placed IABP, which appears to be working satisfactorily. The patient has epicardial pacing wires and is being paced at 90bpm. There has not been a large volume lost through any of the drains. Despite the registrar administering a further 2000mls of fluid and increasing the noradrenaline rate to 1.2mcg/kg/min with an initial response in the blood pressure, the patient's hypotension is deteriorating steadily. The registrar provides you with the latest PA catheter data. What cause of the patient's hypotension would you suspect and how would you confirm it?

HR 118 bpm	C.O. 2.9 L/min
MAP 49 mmHg	C.I. 1.61 L/min/m ²
CVP 22 mmHg	SVR 1970dyne-s/cm ⁵
RV pres 22/10 mmHg	SVRI 3100dyne-s/cm ⁵ /m ²
PA pres 22/12 mmHg	PVR 220 dyne-s/cm ⁵
mPAP 16 mmHg	PVRI 397 dyne-s/cm ⁵ /m ²
PAoP 16 mmHg	SV 25 ml

Answer:

Pericardial tamponade with a retained clot

Confirm by performing a bedside transthoracic ECHO

Rationale:

The patient was initially stable on return from theatre, on the support devices, but has become progressively hypotensive. The PA catheter data suggests an extrinsically compressed right heart – raised CVP with an elevated RV diastolic pressure that is beginning to approximate the PA diastolic pressure and, in turn, the PA occlusion (wedge) pressure. The low MAP, SV, C.O. and C.I. with a tachycardia occurs because of the limitation on the blood volume that can get through the compressed right ventricle. The SVR and SVRI are raised in compensation and because of the noradrenalin (norepinephrine). The tamponade is often not suspected because of the lack of drain output, which has occurred usually because of a clot obstruction, but this is usually a key feature and necessary to generate the tamponade; unless the clot is forming within the pericardial sac itself. A worsening hypotension despite fluid resuscitation and a rising CVP is also often a clue. The source of this tamponade may be a ruptured coronary artery suture or a ventricular perforation.

Monitoring data – Case 4

Question:

A MET call is put out for a 63 year old gentleman on the coronary care unit. He was admitted 4 days ago following an anteroseptal acute myocardial infarct, for which a percutaneous coronary angioplasty and stent procedure was successfully performed. He had been pain free and his heparin infusion had been ceased that morning. This afternoon he became suddenly dyspnoeic, with an SpO₂ of 68%, requiring CPAP of 12cmH₂O to bring them back up to 89%. He is tachycardic, with a BP of 82/47 mmHg (MAP 55 mmHg) and appears diaphoretic. He is urgently transported to the ICU where he is intubated and placed on SIMV (Vt 475ml, PEEP 12cmH₂O, f14, FiO₂ 1.0, Ppk 28cmH₂O), given 1000mls of crystalloid and commenced on noradrenalin (norepinephrine) at 0.07mcg/kg/min and dobutamine at 3mcg/kg/min. The senior registrar floats in a 5-lumen PA catheter, which yields the following data:

HR 124 bpm	C.O. 2.1 L/min
MAP 56 mmHg	C.I. 1.16 L/min/m ²
CVP 6 mmHg	SVR 1904 dyne-s/cm ⁵
RV pres 56/7 mmHg	SVRI 3448 dyne-s/cm ⁵ /m ²
PA pres 56/30 mmHg	PVR 952 dyne-s/cm ⁵
mPAP 39 mmHg	PVRI 1724 dyne-s/cm ⁵ /m ²
PAoP 14 mmHg	SV 18 ml
	SvO ₂ 90%

What is the definitive treatment and list 3 supportive measures that can be taken in the meantime?

Answer:

Definitive treatment = surgical ventriculoseptal repair

Supportive measures:

- LV afterload reduction; e.g. IV nitrate infusion, if the systemic perfusion allows
- Inotrope; e.g. dobutamine 2.5 – 10mcg/kg/min, though it potentially increases the myocardial oxygen demand
- Insertion of an IABP improves peripheral perfusion, reduces the workload of the already compromised myocardium and improves coronary artery perfusion.

Rationale:

The AMI in this patient was in the correct distribution; i.e. antero**septal**. Post AMI acute ventricular septal rupture typically occurs 2 – 8 days after the MI. The PA catheter data suggests a cardiogenic shock state, with high RV and PA pressures. As an acute complication, this could be due to acute heart failure, a papillary muscle rupture resulting in acute mitral regurgitation, or, an acute ventricular septal rupture. The clue is the high mixed venous oxygen saturation (SvO₂), suggesting a left to right shunt. The short term mortality rate is high and surgical repair is the definitive therapy, with an IABP and medical therapy serving as a bridge to theatre.

Monitoring data – Case 5

Question:

A 59 year old gentleman is in your ICU with 65% TBSA burns. He returns from theatre following an extensive debridement procedure. An oesophageal doppler has been inserted and the nurse has requested a review of the latest readings.

HR 96 bpm	FTc 262 mSec
CO 3.8 L/min	PV 58 cm/sec
SV 40 ml	

What intervention would you advise next?

Answer:

Give a 500ml fluid challenge.

Rationale:

His low stroke volume (SV) and short corrected flow-time (FTc – corrected for HR and correlates in a directly proportional manner to preload, as described originally by Singer et al. in Crit Care Med 19:1132, 1991) suggest hypovolaemia as the cause for the low cardiac output (CO). This fits with the clinical scenario. Following the 500ml fluid challenge, his CO , SV and FTc improve, indicating a positive response to filling.

The low peak velocity (PV) suggests an impaired contractility and if the CO had remained low despite an optimised volume state, an inotrope might be the next intervention to consider

Monitoring data – Case 6

Question:

A 60 year old, known alcoholic patient has been admitted through the emergency department earlier today. He had been complaining of abdominal discomfort, increasing dyspnoea and intermittent fevers. He became hypotensive in the ED and received 2000mls of crystalloid and, following a lactate reading of 5mmol/L on a blood gas result, was commenced on noradrenaline at 0.08mcg/kg/min. He was subsequently intubated for invasive ventilation, with an FiO₂ of 0.5 and a PEEP of 10cmH₂O, due to increasing respiratory effort and falling oxygen saturation. Empiric antibiotics have been commenced. A LiDCO monitor is attached and the readings are as follows:

HR 104 bpm	SV 30 ml
MAP 53 mmHg	SVRI 2454 dyne-s/cm ⁵ /m ²
CVP 10 mmHg	SVV 24%
CI 1.4 L/min/m ²	

a) What intervention would you perform?

b) Following your intervention, his MAP still remains 58mmHg despite norpepinephrine 0.4 µcg/kg/min. He is peripherally cool and has an hourly urine of approximately 15mls/hour with a lactate that has fallen to 4.5mmol/L . His measured ScVO₂ is 60% on an FiO₂ of 0.5, with an SpO₂ of 97% and a Hb of 10.5g/dL. LiDCO readings show:

HR 88 bpm	SV 43 ml
MAP 60 mmHg	SVRI 2300 dyne-s/cm ⁵ /m ²
CVP 14 mmHg	SVV 8%
CI 1.6 L/min/m ²	

What intervention would you perform?

Answer:

a) Give a 500ml fluid challenge

b) Commence dobutamine. The use of corticosteroid therapy in this setting remains controversial but could be considered.

Rationale: a) The low CI and SV, with a low CVP despite a PEEP of 10, along with the raised SVV and SVRI, suggest a hypovolaemic, vasoconstricted shock state. A reasonable first line intervention would be to administer a volume challenge, until a euvoalaemic state has been achieved.

b) CI and SV remain low, despite improvements in the MAP and CVP. The SVV is now <10% indicating a low likelihood of volume responsiveness. The SVRI remains at the higher end of the normal range, which is likely to reflect the increased noradrenalin dosing. The picture is one of euvoalaemia, vasoconstriction and cardiogenic shock. Therefore, an inotrope is a reasonable intervention at this stage. If there is still a poor CI and SV despite optimal inotropy and there are no contraindications, it would be reasonable to consider inserting an intra-aortic balloon pump, however, you would need to be extremely cautious in the presence of active sepsis, especially if there is concern regarding immunocompromise.

Monitoring data – Case 7

Question:

A 42 year old gentleman has been in the ICU for 24 hours, following admission for severe sepsis due to ureterolithiasis causing an obstructive uropathy. He is on empiric antibiotics and has had a right sided percutaneous nephrostomy tube placed under radiological guidance. His latest PiCCO data is provided to you.

BP 84/42 mmHg	SVV 18%
HR 128 bpm	SVI 15 ml/m ²
	GEDVI 675 ml/m ²
CVP 6 mmHg	ITBI 805 ml/m ²
MAP 56 mmHg	EVLWI 3.5 ml/kg
C.I. 1.93 L/min/m ²	CFI 1212 ml/m ²
SVRI 2073 dyne-s/cm ⁵ /m ²	



a) How would you correct the deficit?

An hour after your intervention, you note the following PiCCO display.

BP 88/46 mmHg	SVV 8%
HR 115 bpm	SVI 26 ml/m ²
	GEDVI 795 ml/m ²
CVP 16 mmHg	ITBI 1200 ml/m ²
MAP 58 mmHg	EVLWI 11.6 ml/kg
C.I. 2.82 L/min/m ²	CFI 5120 ml/m ²
SVRI 991 dyne-s/cm ⁵ /m ²	



b) How would you respond?

Answer:

- a) Intravenous fluid challenge; e.g. 500ml colloid.
- b) Commence a vasopressor and titrate to MAP and SVRI; e.g. noradrenalin at 0.05 mcg/kg/min

Rationale:

a) PiCCO gives a global assessment of cardiac preload (GEDVI, SVV), afterload (MAP, SVRI) and contractility (SVI, CI, CFI), along with an estimation of lung tissue water (EVLWI). At the first assessment of this patient, the PiCCO pattern is one of inadequate preload (low CVP, ITBI, GEDVI and SVV) with resulting reduced cardiac output and compensatory vasoconstriction causing increased afterload (raised SVRI). Additionally, the EVLWI is low, suggesting that there is not a significant quantity of pulmonary oedema. Therefore, a fluid challenge, monitoring the response in SVV, MAP and CFI is the first intervention.

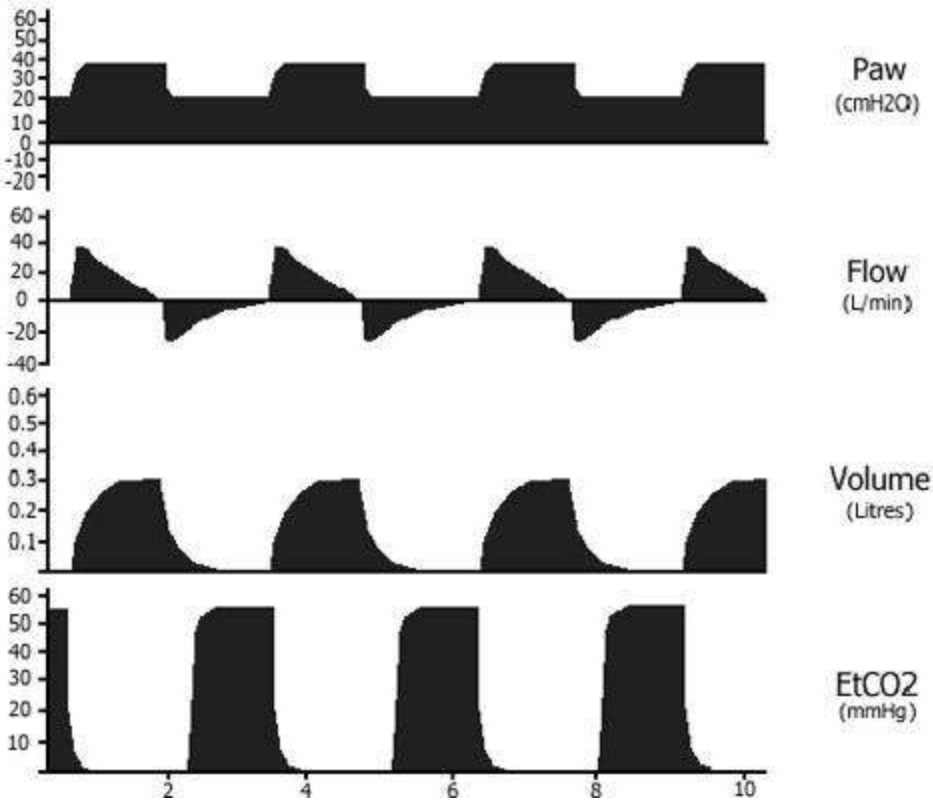
b) On the second assessment, following the fluid challenge, the markers of preload are raised or at the higher end of the normal range, suggesting that the patient is adequately filled. Indeed, there has been improvement, with an increase in the cardiac index, SVI and CFI. However, the BP and MAP remain low, indicating that a haemodynamic deficit remains. Having corrected the volume deficit, the SVRI (afterload marker) is now low which, along with the low systemic diastolic pressure, suggests peripheral vasodilation, as would be expected with septic shock. Additionally, the EVLWI is raised, indicating that sufficient volume has been administered, or acute lung injury has progressed enough, to tip the patient into pulmonary oedema. Therefore giving further intravenous fluid challenges are unlikely to be of additional benefit, so commencing a vasopressor would be the appropriate response

Monitoring data – Case 8

Question:

This patient is being ventilated with an FiO₂ of 0.9.

- a) What type of pulmonary deficit is suggested by the ventilator waveform displayed below?
- b) List 8 causes of this pattern of pulmonary deficit.



Answer:

a) Poor pulmonary compliance during PCV, with hypercapnoea, suggesting impaired gas exchange

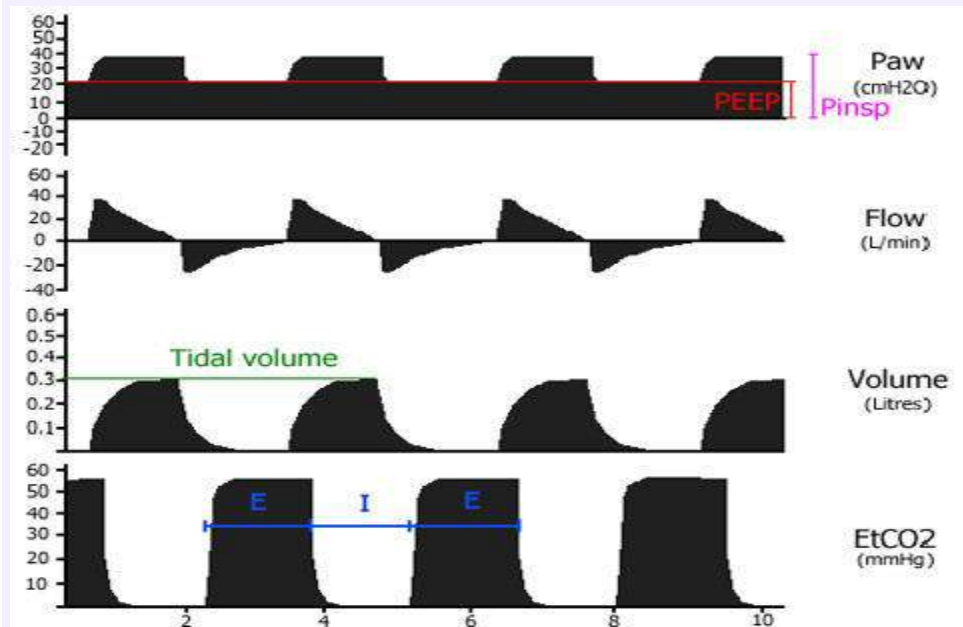
b) Causes of acute lung injury; e.g. ARDS:

- 1. Sepsis
- 2. Massive aspiration pneumonitis
- 3. Inhalation injury
- 4. Fat embolism
- 5. Amniotic fluid embolism
- 6. Pancreatitis induced acute lung injury
- 7. Major trauma
- 8. Massive blood transfusion (TRALI)

Rationale:

The ventilator waveforms and limits suggest pressure control ventilation employing the ARDS-Net ventilation strategy of $V_t \leq 6\text{ml/kg}$ and a PEEP matched to the FiO_2 . The I:E ratio is approximately 1:1 in keeping with a refractory hypoxia strategy. Permissive hypercapnoea is also evident.

Additional reasons for employing an ARDS ventilation strategy include bilateral pulmonary contusions, reperfusion injury, burns $> 25\%\text{TBSA}$ and cardiopulmonary bypass induced lung injury.)



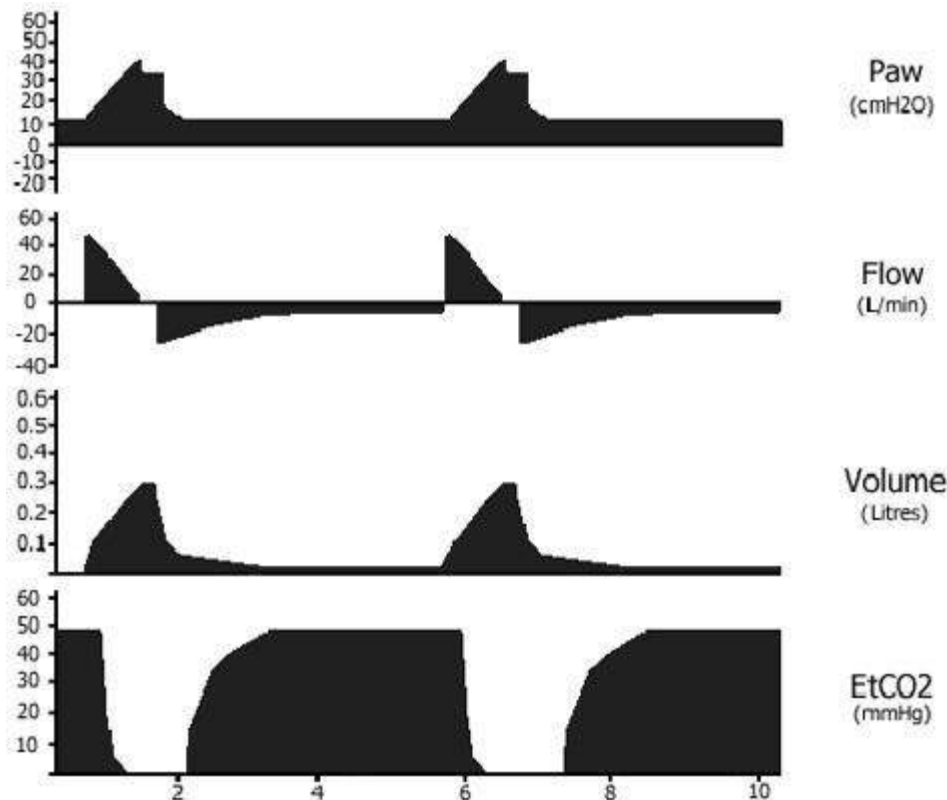
ARDS PCV – Marked

Settings: PCV, P_{insp} 35 cmH₂O, PEEP 20 cmH₂O, PS 10 cmH₂O, V_t 300 ml, FiO₂ 0.9, f 24 bpm, I:E 1:1, MV 7.2 L.

Monitoring data – Case 9

Question:

List 6 therapies for the condition that is reflected in the following ventilator display of a 23 year old with acute respiratory failure.



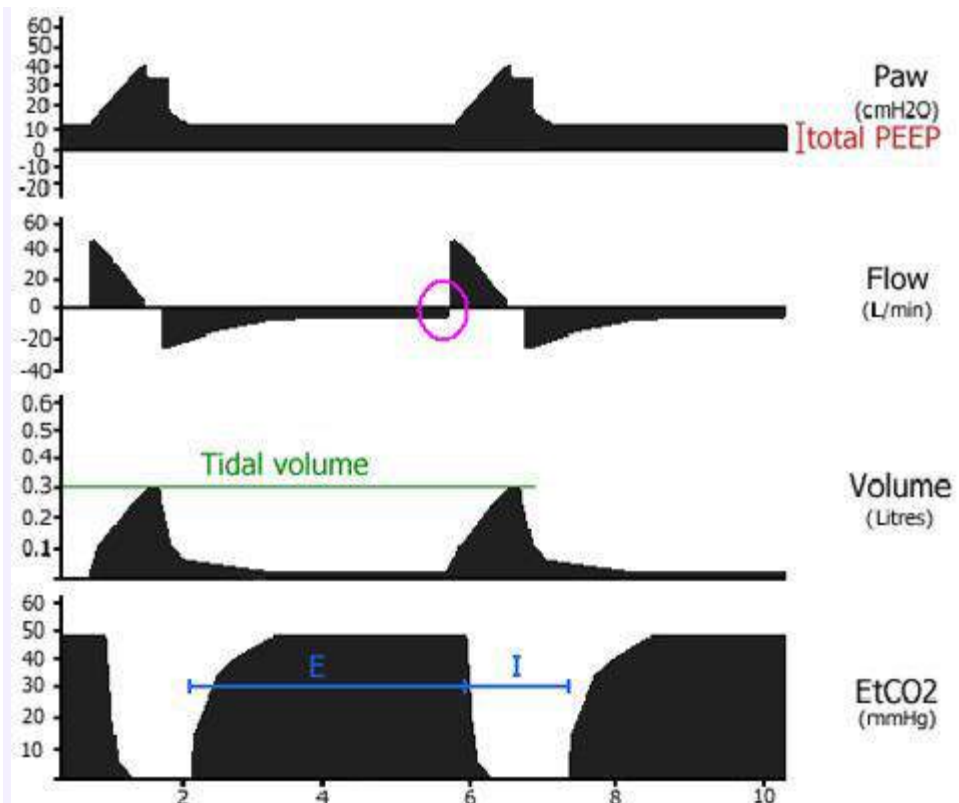
Answer:

- Salbutamol, nebulised or IV infusion
- Adrenalin (Epinephrine) infusion
- IV hydrocortisone
- IV magnesium
- IV theophylline
- Heliox ventilation

(Additional therapies include nebulised ipratropium bromide, a ketamine infusion and the use of bronchodilating inhaled anaesthetic agents)

Rationale: The ventilator waveforms and limits suggest volume controlled ventilation with a decelerating ramp flow pattern, using a low tidal volume, slow rate, prolonged I:E ratio ventilation strategy, with a shark fin EtCO₂ waveform whose height indicates hypercapnoea. This strategy is consistent with that used for ventilating severe asthma, which fits with the age of the patient and their acute presentation. Some centres prefer to use pressure controlled ventilation.

The total PEEP is about cmH₂O, but remember that this will reflect the combined set PEEP and intrinsic PEEP, whose presence is suggested by the failure of the Flow-Time scalar to return to baseline. The set PEEP is usually set to be just below the estimated iPEEP. Some use a value of 2/3rds of the estimated iPEEP. Others use the Lower Inflection Point (LIP) on a Volume-Pressure curve.



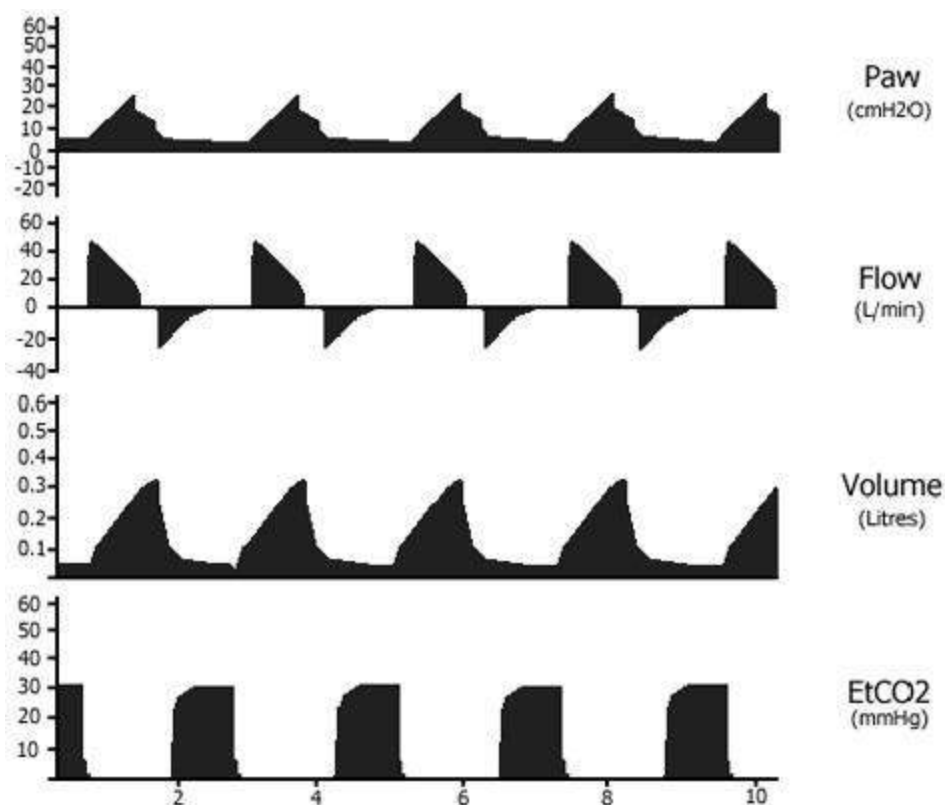
Asthma waveform – Marked

Settings: SIMV, PS 10, Vt 300, FiO2 0.6, f 8, I:E 1:3, MV 2.4, Flow fails to return to baseline at end expiration (Pink ellipse), EtCO2 51. The flow-time scalar shows the expiratory flow failing to return to baseline, which is suggestive of the presence of intrinsic PEEP (iPEEP) due to dynamic hyperinflation

Monitoring data – Case 10

Question:

A 25 year old gentleman has been mechanically ventilated for 5 days in the ICU following admission for polytrauma that included a traumatic brain injury, multiple stab wounds to the chest and a left ulnar shaft fracture. There is a massive air leak from the chest drain. The ventilator display shows the following waveforms, with an FiO2 of 0.7. Outline the principles of management of this condition and list 4 therapeutic options.



Answer:

Principles:

- minimise the flow across the fistula by reducing the transpleural pressure gradient to as low as is practical and safe
- extubate as soon as practical

Therapeutic options

1. Ventilation strategy - low V_t , slow rate, short inspiratory time, minimum PEEP to maintain oxygenation
2. Isolated lung ventilation – double lumen ETT, bronchial blocker
3. Surgical repair
4. Positioning – good lung up may reduce the fistula leak

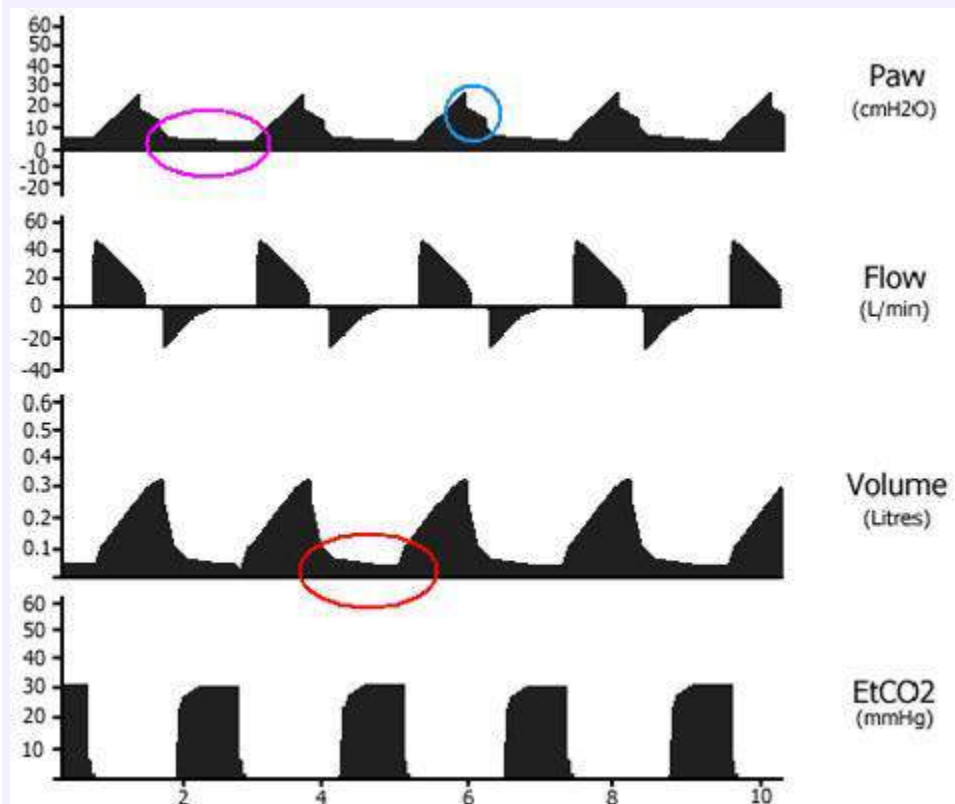
(Additionally, regular airway suctioning and use of bronchodilators minimises expiratory resistance, need to maintain enough PEEP and negative suction on the ICC to prevent lobar atelectasis while avoiding an excessive transpleural gradient, nutritional support is important to assist healing and high frequency ventilation is an option. Note however, that while these strategies can improve oxygenation and reduce flow across the fistula, none have been shown to improve the overall patient outcome)

Rationale:

The pressure-time scalar demonstrates loss of airway pressure during the inspiratory pause (Blue ellipse) and loss of PEEP (Pink ellipse) (implies large leak).

The volume-time scalar shows the expiratory portion of the graph failing to return to baseline (Red ellipse), suggesting that the expiratory V_t is much less than the inspiratory V_t and more so than would be accounted for purely by tubing compliance; i.e. there must be a leak. In the context of penetrating chest trauma, suspect a bronchopleural fistula and check the chest drains for a persistent bubbling.

The EtCO₂ waveform is shortened as ETT expiratory flow ceases early (large leak).



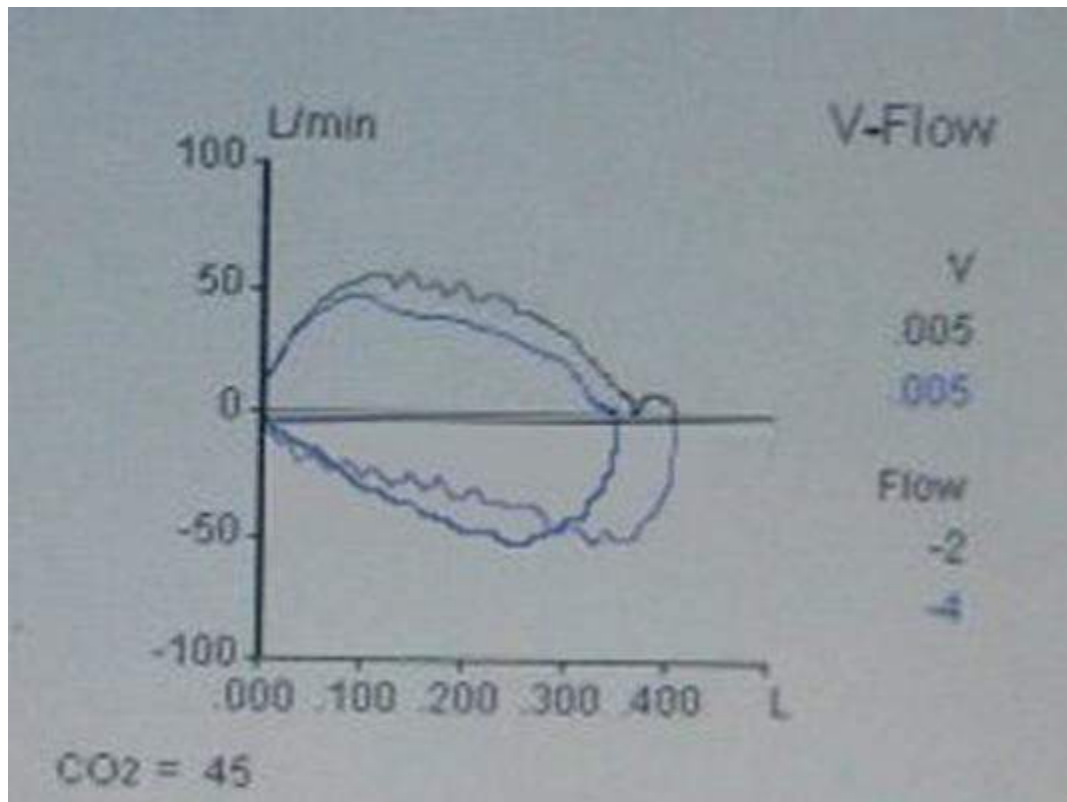
BPL waveforms - Marked

Settings: SIMV, V_t 350, PEEP 5, PS 8, FiO_2 0.7, f 24, I:E 1:1.5, MV 8.4, Volume scalar does not return to baseline (Leak)

Monitoring data – Case 11

Question:

A patient in your ICU, whose "low flow" alarm has begun to sound repeatedly over the last half hour, has the following flow-volume loop on the ventilator display. What would you request of the patient's nurse?

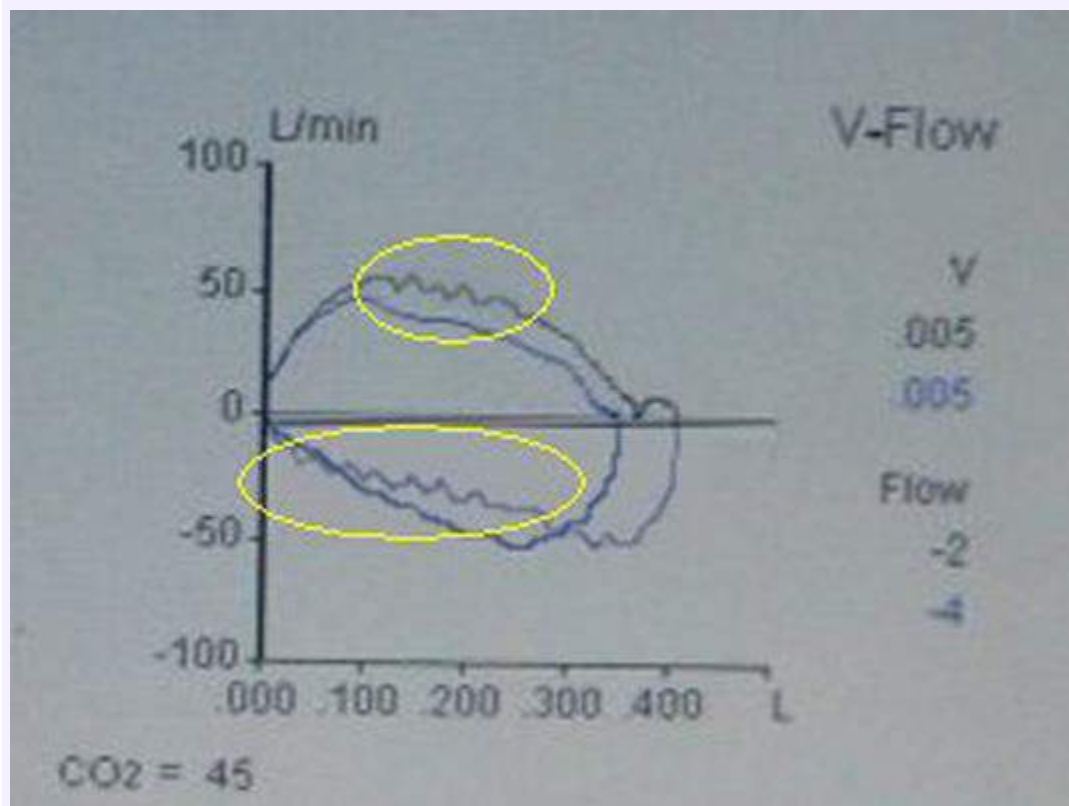


Answer:

1. Check the expiratory limb of the ventilator tubing for excess rain-out or secretions
2. Suction the endotracheal tube
3. Tracheal toilet

Rationale:

The flow-volume loop demonstrates flow oscillation during the inspiratory and, more noticeably, the expiratory limbs (Yellow ellipses) of the loop. These oscillations are due to the effect of the ventilator gas rippling through fluid, which may be an accumulation of airway secretions or excessive rain-out trapped in a dependant loop of ventilator tubing. Note: The blue loop is a reference loop that has been recorded from an earlier time and can be used to compare the change in ventilation dynamics when alterations are made to the settings.



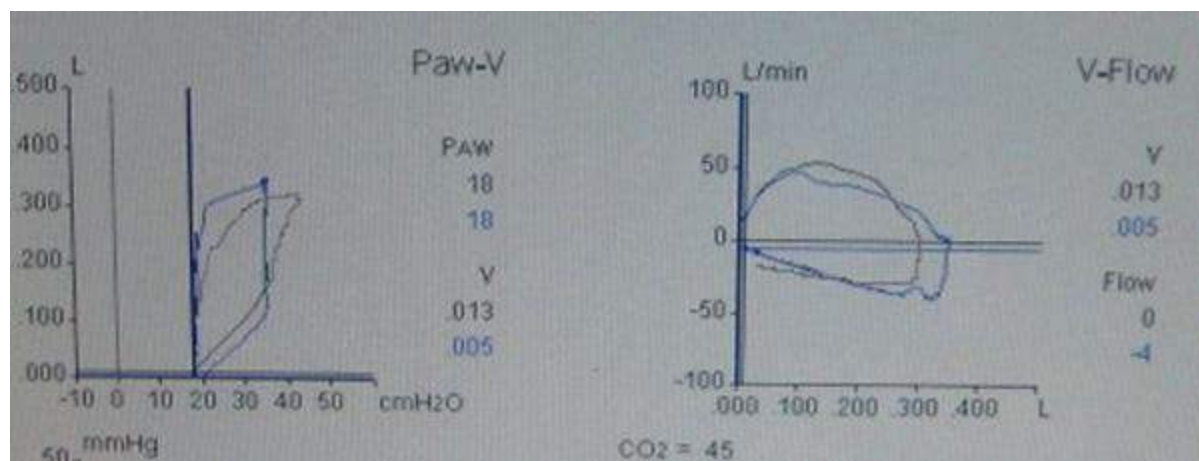
Flow vol tube secretions - Marked

Jean Guglielminotti, MD, Marc Alzieu, MD, Eric Maury, MD, Bertrand Guidet, MD and Georges Offenstadt, MD.
 Bedside Detection of Retained Tracheobronchial Secretions in Patients Receiving Mechanical Ventilation* Is It Time
 for Tracheal Suctioning? Chest 2000;118 (4):1095-1099.

Monitoring data – Case 12

Question:

The "high pressure" alarm has been sounding on the ventilator of this patient, who is day 3 in your unit with ARDS due to H1N1 Influenza A. The ventilator loops are displayed below. What options are there for ameliorating this problem?

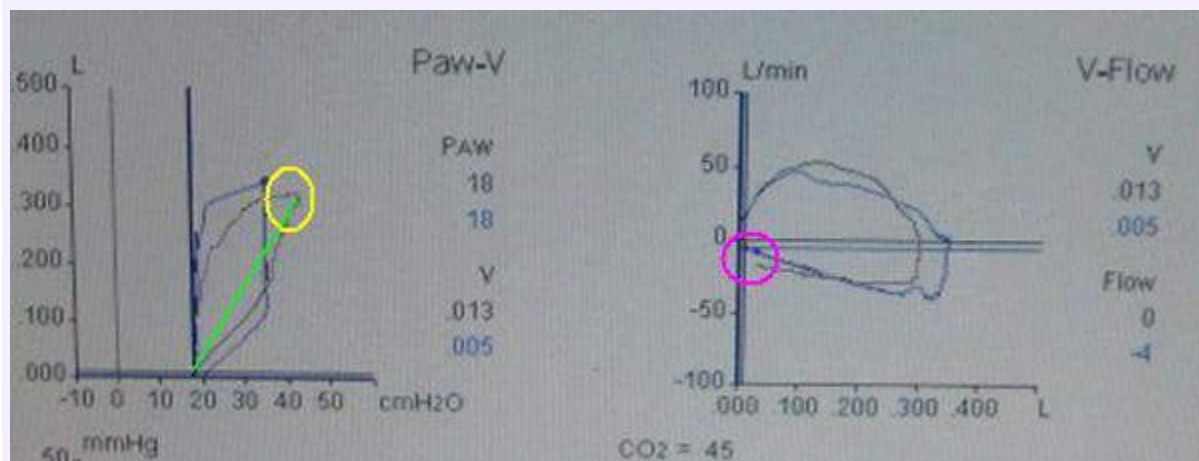


Answer:

1. Provide a longer expiratory time; e.g. prolonged I:E ratio.
2. Decrease the respiratory rate (f)
3. Set ventilator PEEP to no more than 75 – 85% of the intrinsic PEEP (iPEEP), as measured by an expiratory hold on the pressure-time scalar.
4. Avoiding excessive tidal volume (V_t).
5. Use of bronchodilators if reversible bronchospasm is suspected.
6. Tracheal and ETT toilet.
7. Use the largest calibre ETT feasible.
8. Ensure adequate analgesia and anxiolysis.
9. Ensure the patient is adequately sedated and, if necessary has neuromuscular blockade, if it is suspected that the patient is breathing out forcefully against the ventilator. Alternatively, if the required ventilator support is minimal, and invasive ventilation is no longer required, extubate the patient.

Rationale:

Diagnosis: excess intrinsic PEEP The black loop on the pressure-volume loop demonstrates a classic "bird's beak" appearance (Yellow ellipse) and decrease in compliance (Green line) associated with end-inspiratory dynamic hyperinflation. The flow-volume loop demonstrates an open loop, with the expiratory limb failing to return to baseline before the next inspiratory delivery (Pink ellipse), similar to a flow-time scalar.



Intrinsic PEEP loops - Marked

Monitoring data – Case 13

Question:

The following patient was weaning from ventilation using a gradual reduction with a Pressure Support Ventilation (ASB) mode and a reducing level of support above PEEP. The nurse is worried that the flow trigger sensitivity has been set unusually high and wants to reduce it. Do you agree? What are the problems associated with setting the trigger sensitivity too high and too low?



Answer:

Yes - common sensitivity setting is 3L/min

Value set too high (Low sensitivity)

- The patient must work much harder to create the necessary flow to trigger a breath, the absence of which may result in erroneous triggering of mandatory apnoea ventilation

Value set too low (High sensitivity)

- Auto-triggering

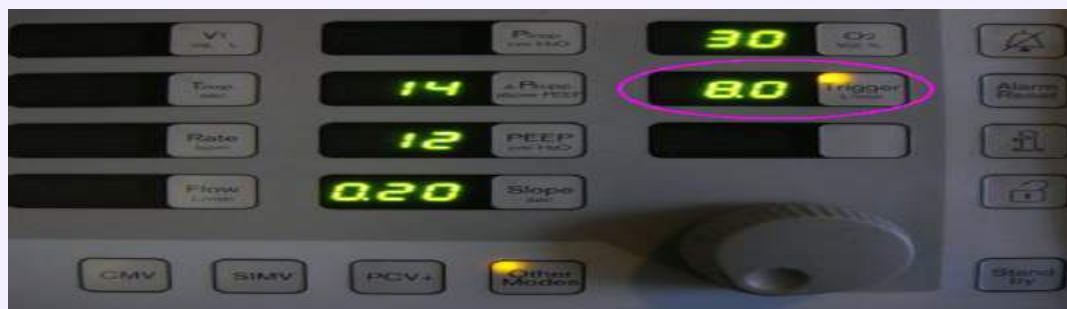
Rationale:

Trigger sensitivity refers to how easy or difficult it is for the ventilator to detect the patient's respiratory effort. The smaller the flow to be detected (difference between inspiratory and expiratory limb flows detected by the ventilator) the more sensitive the trigger.

A trigger sensitivity of 8L/min is unusual and likely to be too high. A common sensitivity setting is 3L/min.

If the setting is too low then ventilator asynchrony may arise from failure to synchronise pressure support of the patient's spontaneous breaths as a result of detecting non-breathing impulses affecting intrathoracic pressure, such as cardiac oscillations. This can result in the ventilator delivering breaths out of phase with the patient's respiratory efforts.

If the setting is too high then the ventilator will fail to detect respiratory efforts and fail to synchronise pressure support of spontaneous breaths. In PSV (ASB) mode this will result in the triggering of mandatory apnoea breaths.

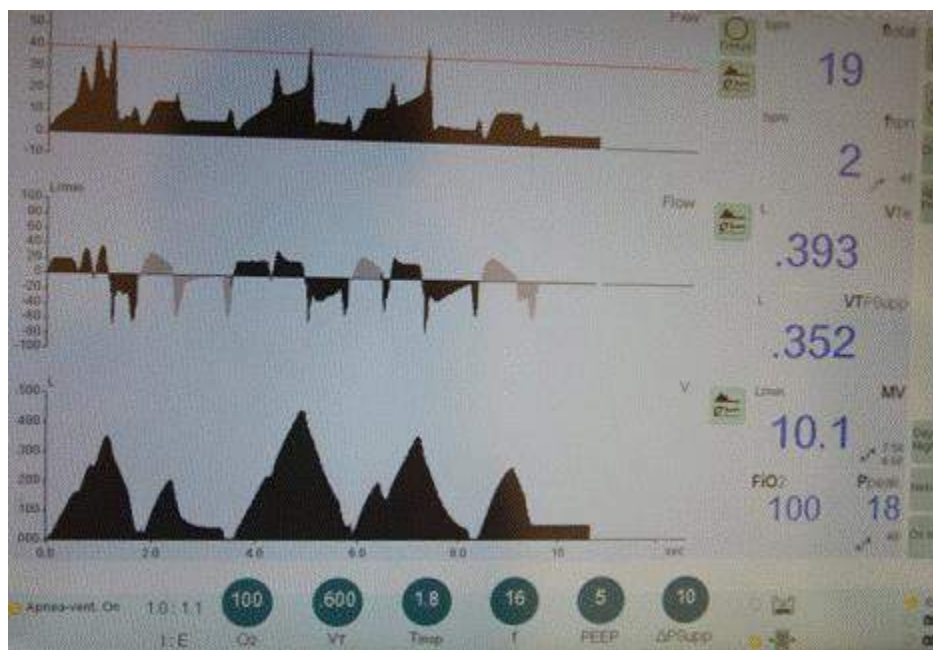


high trigger - Marke

Monitoring data – Case 14

Question:

A 25 year old gentleman has been admitted to your ICU following a severe traumatic head injury, for which an ICP monitor and EVD have been sited. After the first 72 hours his ICPs have settled, without needing any intervention beyond sedation and haemodynamic control. This morning his sedative infusions were decreased and the neurosurgeons are considering removing the EVD. Your registrar is seeking assistance as she is having difficulty with the patient's ventilation, which has been set in an SIMV Volume Control with Pressure Support mode. What do you think is the cause of this difficulty? What are the potential aetiologies and how will you manage the ventilation?



Answer:

Cause of ventilator difficulty = ventilator dysynchrony

Potential aetiologies:

1) Ventilator settings

- Mandatory breath rate (*f*) set too high in a patient capable of spontaneous breaths
- Trigger sensitivity too low (Value set in excess of 3L/min)
- The I:E ratio of 1:1 may be poorly tolerated by a patient who is not deeply sedated +/- under neuromuscular blockade.

2) Patient agitation

- Cerebral agitation from TBI
- Emerging sepsis (e.g. ventilator associated pneumonia, ventriculitis)
- Drug withdrawal (unlikely to be due to withdrawal of the sedative agents, but may be unmasking an underlying illicit drug or alcohol withdrawal)
- Pain / discomfort

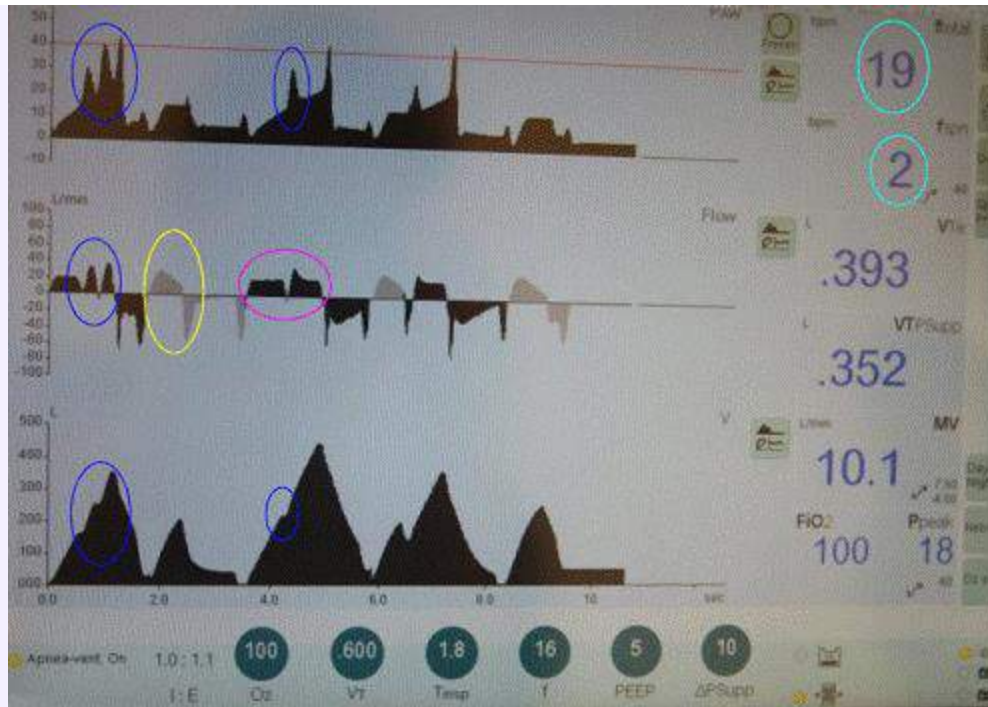
Management

- Change ventilator mode from volume control to pressure support, to allow spontaneous breathing. Ensure a sufficient level of pressure support is set to achieve adequate tidal volumes. Ensure adequate minute volume and monitor ICP, EtCO₂ and/or PaCO₂ closely as there is a risk that hypercapnoea will be poorly tolerated after a TBI.
- Reduce mandatory breath rate, if mandatory breaths are still deemed necessary.
- Lengthen I:E ratio from 1:1 to 1:1.5-2
- Confirm appropriate trigger sensitivity (e.g. if flow triggered, then 2 – 3 L/min)
- Treat reversible aetiologies – analgesia for pain, benzodiazepines for withdrawal, verbal reassurance, ensure appropriate ETT position, suctioning of excess secretions.
- If agitation persists despite appropriate management of reversible causes, consider other drugs for cerebral agitation (e.g. clonidine, dexmedetomidine).
- If weaning of the ventilator is not feasible, may need to re-sedate in order to gain control of ventilation.

Rationale:

All three time scalars show a chaotic series of peaks and troughs that seem to be superimposed on the background waveforms. The Flow-Time scalar demonstrates both mandatory breaths (pink ellipse) and spontaneous breaths (yellow ellipse). The mandatory breaths are interrupted by short, sharp troughs and peaks, which may be spontaneous respiratory efforts or coughs. This is reflected in both the Pressure-Time and Volume-Time scalars (blue ellipses).

Despite all of these peaks and troughs, the ventilator screen has recorded only 2 spontaneous breaths, on top of the 16 mandatory breaths per minute (light blue ellipses). Again this suggests that either there is a problem with trigger sensitivity or the patient is coughing during both the mandatory and spontaneous breaths.

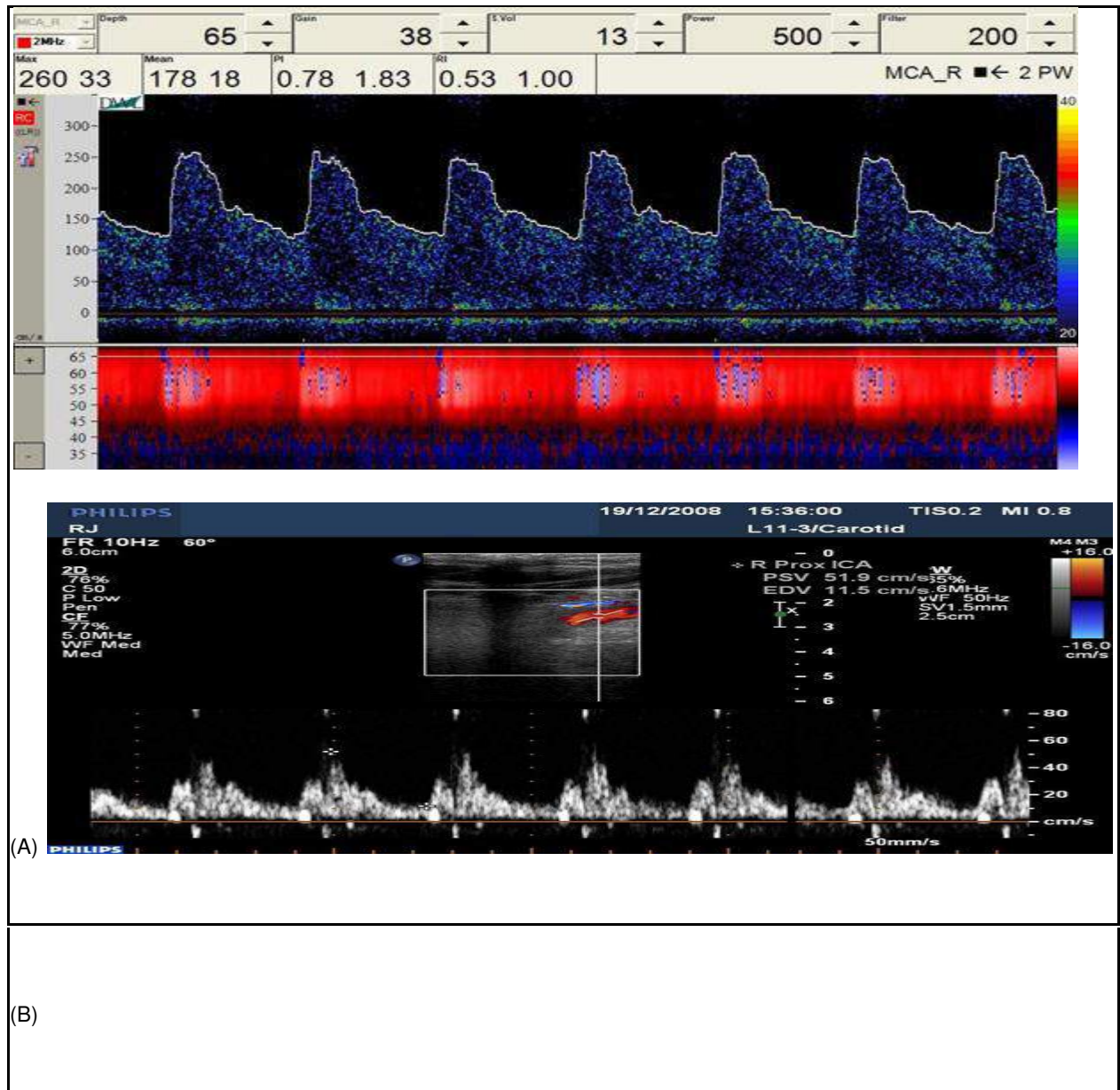


Ventilator dysynchrony – marked

Monitoring data – Case 15

Question:

A 36 year old patient is day 5 of his admission to the ICU following a witnessed collapse. The CT brain showed a Fischer grade 3 subarachnoid haemorrhage. His level of consciousness deteriorated from withdrawing from a central noxious stimulus, to extension to the same stimulus. His pupils remain equal and reactive to light. His EVD does not appear to have increased in its output rate. The following investigation is performed.



- What is this investigation?
- What does it demonstrate?
- List 3 management options.

Answer:

- Image A = Transcranial Doppler study of the right MCA. Image B = Right internal carotid artery

b) Moderate cerebral artery vasospasm in the right MCA with a Lindegard ratio of 5 ($260/52 \text{ cm.s}^{-1}$)

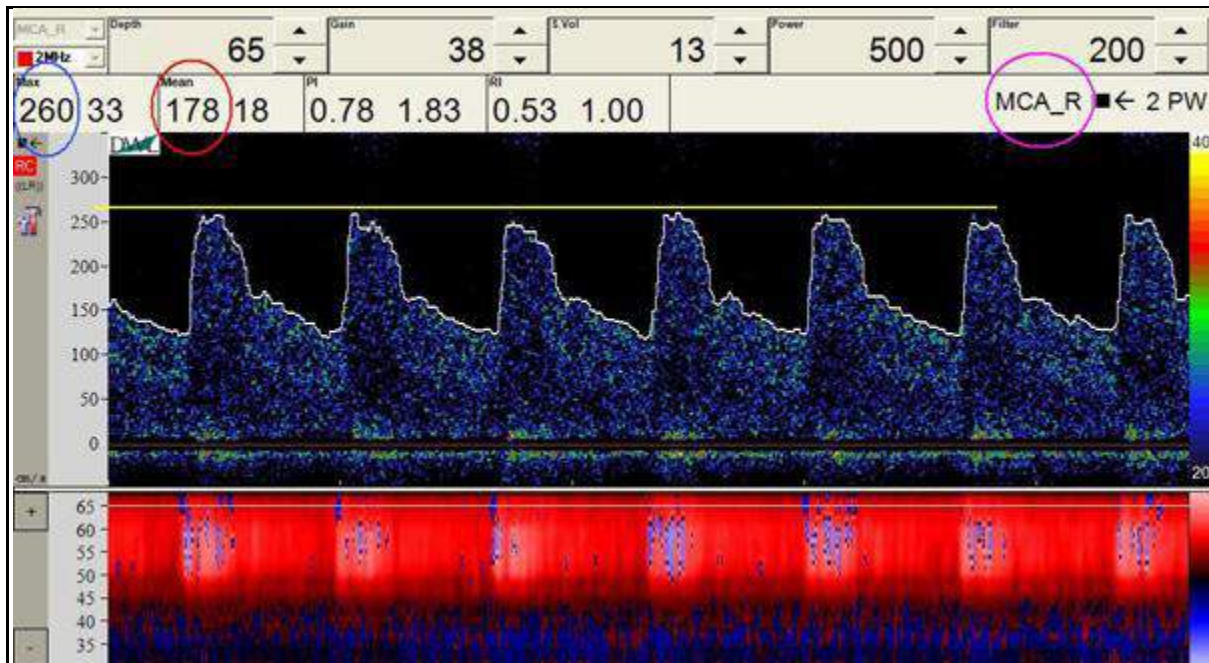
c) 1. Ensure the patient is receiving nimodipine

2. Radiologically guided intra-arterial verapamil

3. Percutaneous angioplasty

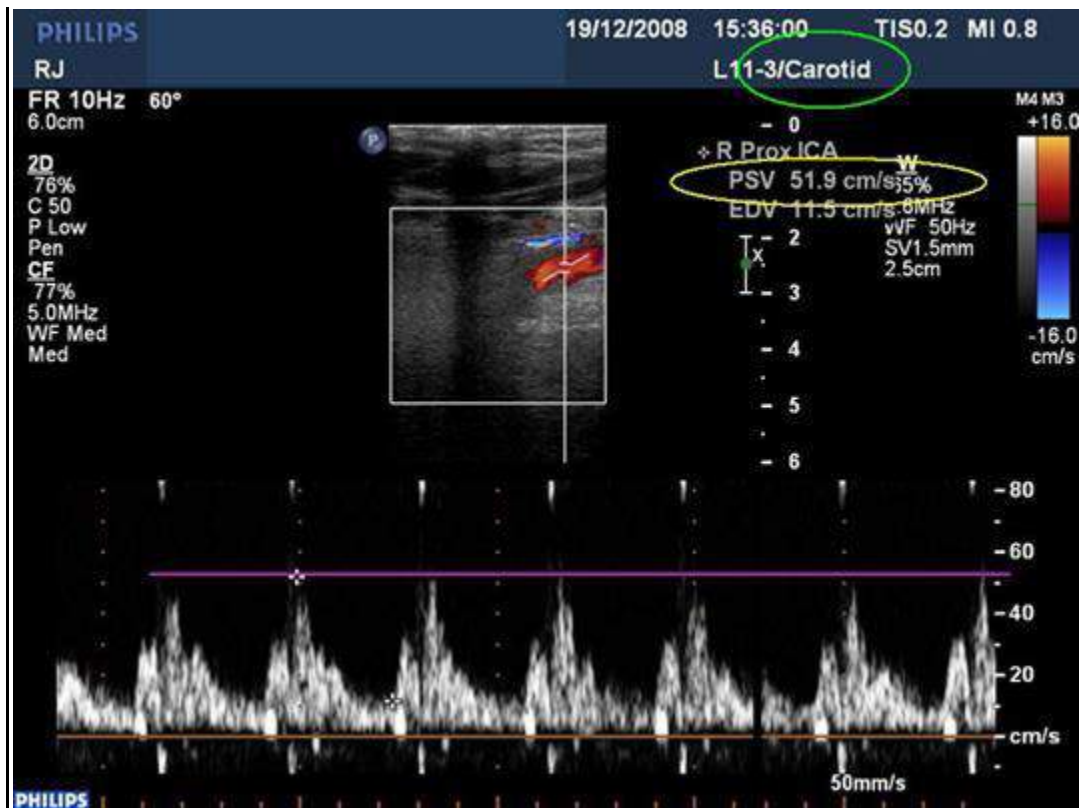
Rationale:

The mean MCA velocity (Red ellipse on Image A) is 178 cm/sec, which suggests mild to moderate vasospasm. The maximum MCA velocity (Blue ellipse and horizontal yellow line on Image A) divided by the peak ICA systolic velocity (Yellow ellipse and horizontal pink line on Image B) yields the Lindegard ratio, which at 5 indicates moderate cerebral vasospasm. (See DVD Chapter 6 – Data interpretation; Table 6.17).



(A)

TCD vasospasm post SAH - marked



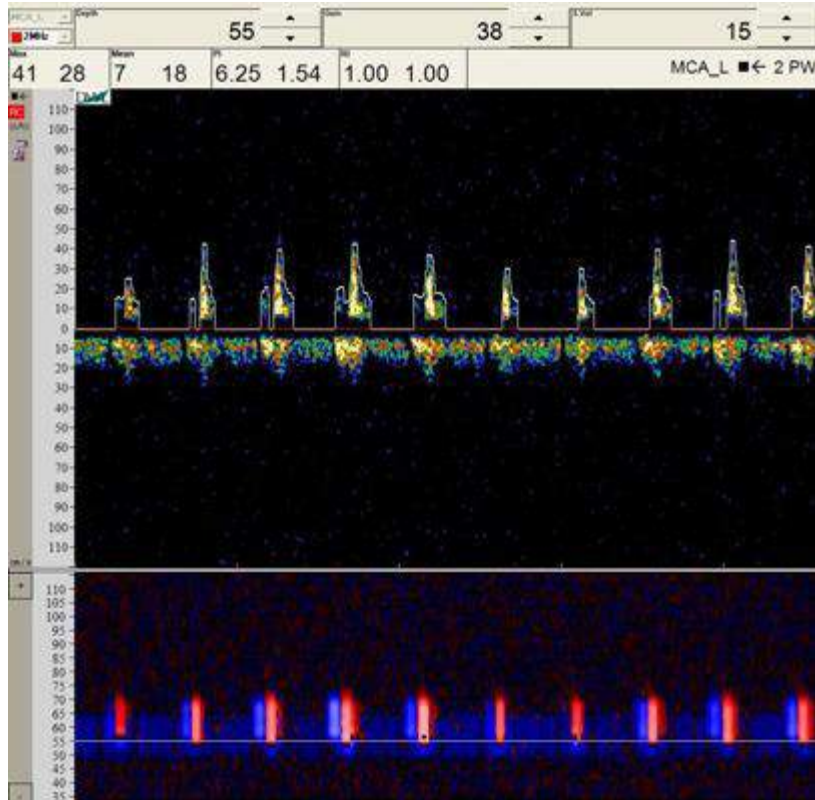
(B)

ICA Doppler - Marked

Monitoring data – Case 16

Question:

A 22 year old female, who was admitted following a prolonged episode of acute severe asthma. The responding ambulance noted a weak carotid pulse, with no respiration. CPR was performed and she was intubated at the scene and given IM and IV adrenaline. She remained sinus tachycardia during transport. She was rapidly transported to the ICU for further care. Her neuromuscular blockade was ceased on day 2 and her sedation was ceased later that day. 2 days later she still has not had a motor response to a noxious stimulus and her pupils remain unreactive. A CT brain shows no abnormalities and an EEG is reported as demonstrating no evidence of seizure activity. A transcranial Doppler study is performed.



TCD report: M-mode demonstrates discontinuous brief blue/red signals at the same depth for both the right and left MCA at 55 and 70mm. The Doppler spectrum demonstrates high resistance flow.

How can the result of the TCD be used in her further management?

Answer:

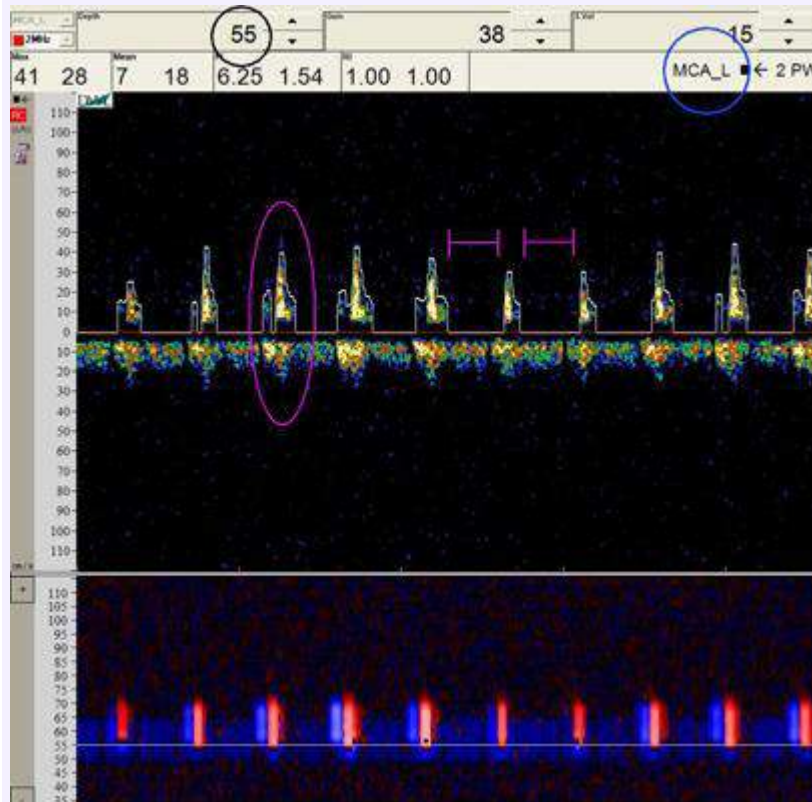
The TCD result suggests that there is very limited MCA flow with a significant degree of proximal occlusion. Both the left and right MCA are affected at two separate distances, suggesting that this is a global process; in this context, global cerebral oedema, most likely due to hypoxic-ischaemic encephalopathy.

As there is flow demonstrated, albeit very limited, brain death cannot be diagnosed by this imaging modality. However, TCD is not an accepted definitive investigation for making this diagnosis and is instead often used to determine the optimal time to perform a 4-vessel angiogram with a reasonable chance of avoiding a residual flow, or a false positive or false negative result.

Otherwise, for now treatment would continue until such time as brain death is clinically or radiologically established, or a decision to withdraw curative treatment on the grounds of futility (some prefer the term "lack of therapeutic benefit") is made.

Rationale:

In addition to the answer given above, the image from the left MCA (Blue ellipse) TCD at 55mm (Black ellipse) demonstrate a phenomenon known as "Thump flow", where a column of fluid travels along a tube and meets a tight restriction proximal to the point of Doppler measurement. The "Thump" is the wave reflected back off the barrier and shows up as a small sharp upstroke associated with a small sharp flow reversal wave (Pink ellipse). There is little or no flow in between the waves (Pink bars).



Rt MCA thump at 55 - Marked

Monitoring data – Case 17

Question:

A 36-year-old male experienced an out of hospital cardiac arrest requiring 30 minutes of CPR after injecting amphetamines. The initial rhythm was Ventricular Fibrillation. He was initially cooled for 24 hours to 34.5°C. By day 6 he still had not woken up and had sluggishly reactive pupils. His GCS was 3. A CT brain scan was initially normal and an MRI on day 5 demonstrated multiple areas of probable infarction consistent with a hypoxic-ischaemic brain injury. He had somatosensory evoked potentials performed to assist prognostication. How would you interpret the result?

		RIGHT MEDIAN		LEFT MEDIAN	
		Latency (msec)	Amplitude (μ V)	Latency (msec)	Amplitude (μ V)
Brachial	N9 :	11.1	3.3	10.8	2.8
Cervical	N11 :				
	N13 :	14.7	1.3	14.6	1.3
	N14 :	14.7	1.3	14.6	1.3
Cortical	N20 :	-	-	-	-
Arm Length (cm) :		-			

Comment: The potentials at Erb's point and the cervical spine are within normal limits. The scalp potentials are absent bilaterally.

Answer:

The results are consistent with reduced cerebral impulse conduction, consistent with a severe hypoxic-ischaemic brain injury. The prognosis is poor for a functional recovery.

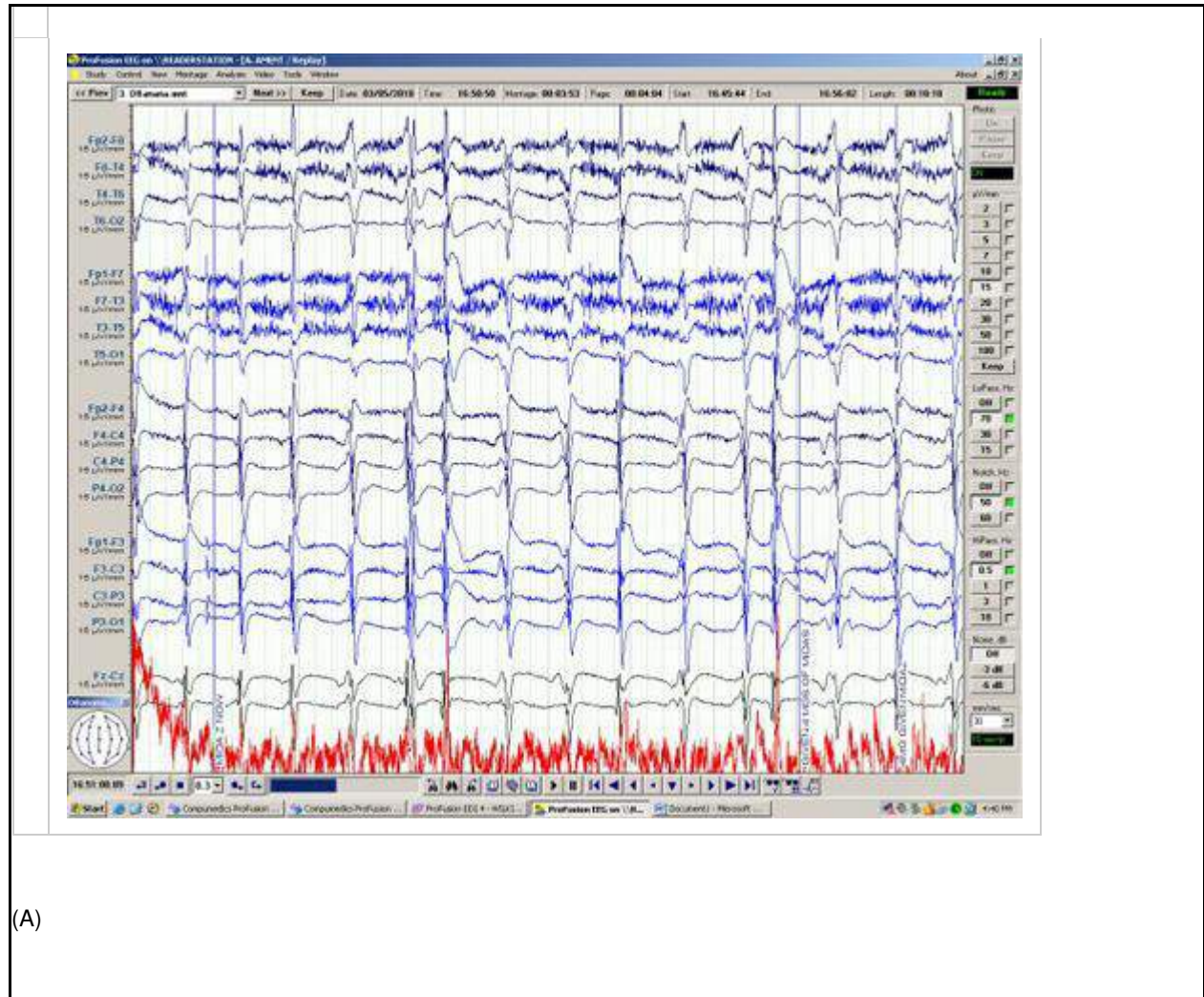
Rationale:

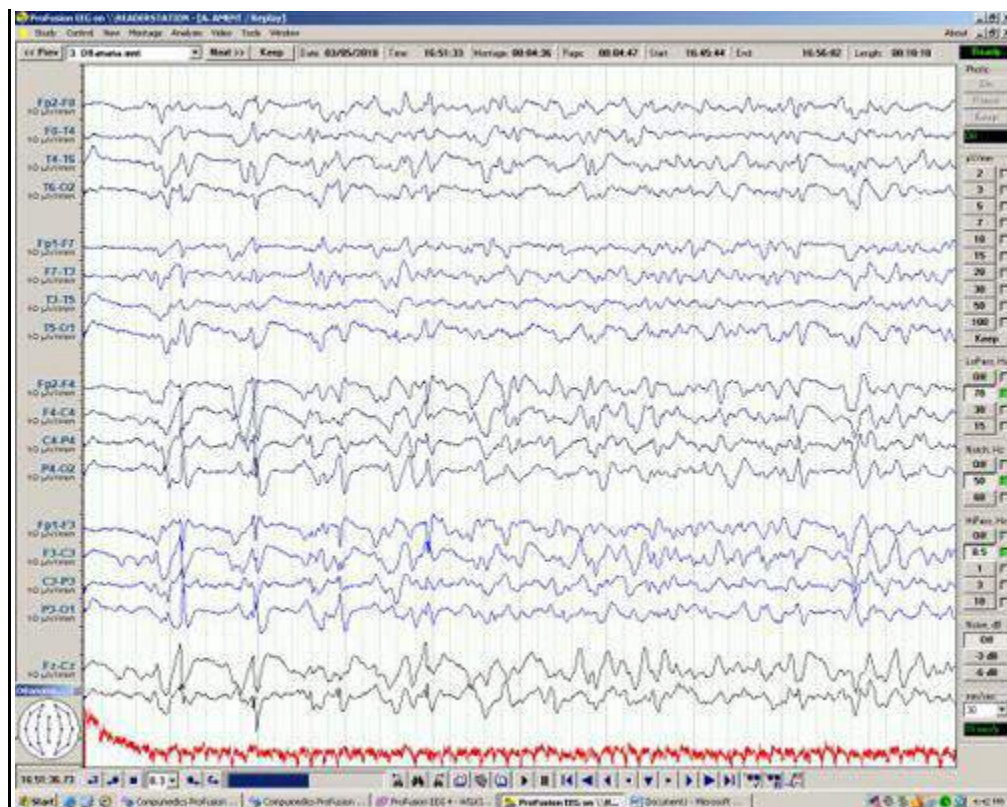
The SSEP data and comment indicate that an electrical impulse initiated peripherally, travels normally as far as the cervical N14 recording point, but never arrives and the cortical N20 recording point, on both the right and left sides. The N14 recording point monitors at the cervicomedullary level, so failure of impulse transmission beyond this level bilaterally is consistent with an extensive brainstem and/or cerebral loss of function, including brain death.

Question:18

A 60-year-old woman with known chronic renal failure secondary to chronic glomerulonephritis, experienced a cardiac arrest 2 days ago due to hyperkalaemia. She was initially treated with therapeutic hypothermia and renal replacement therapy.

On day 5 she is not waking up and has been noted to have intermittent twitching of her face and limbs. An EEG was ordered and a sample of activity is shown both before (Image A) and after a bolus of intravenous midazolam (Image B). How would this influence your management?





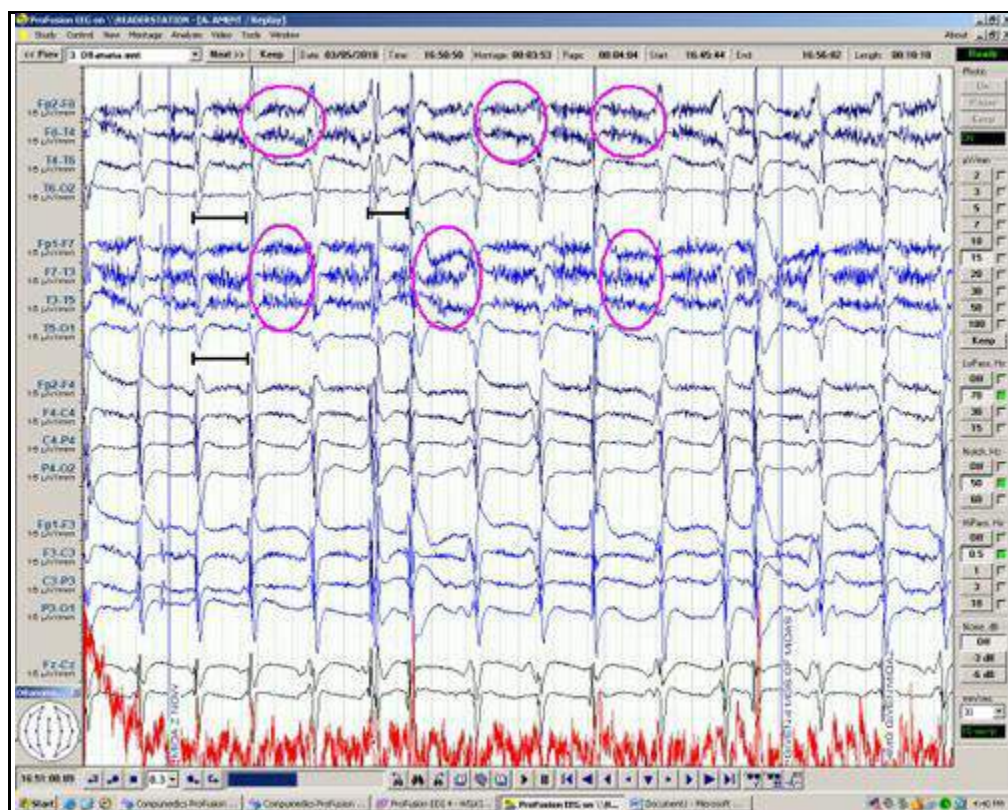
(B)

Answer:

Pre and post midazolam EEG suggest abolition of electrical seizure activity. Therefore, failure to wake may be a non-convulsive status epilepticus. I would attempt to control the seizures, in order to be better able to prognosticate. However, the use of antiseizure medications such as the benzodiazepines potentially introduce further uncertainty if she still does not wake. Additionally, status electrical activity post OHCA is associated with a universally poor outcome.

Rationale:

The trace is consistent with status epilepticus with periodic generalized spike to polyspike activity at 1.5Hz (Pink ellipses). It is abolished by the midazolam. The post midazolam study shows a moderate generalized slowing consistent with a post-ictal state (The black bars are longer in the post midazolam EEG than in the pre midazolam study). The study would prompt administration of anticonvulsant drugs, as this is a potentially reversible cause of failure to wake up after cardiac arrest.



(A)

EEG pre Midazolam – Marked



(B)

EEG post Midazolam - Marked

Monitoring data – Case 19

Question:

A 34-year-old man was admitted with rapidly progressive weakness that started in the lower limbs but now involves the upper limbs as well. Tone was flaccid and deep tendon reflexes were absent. He was cognitively intact and complained of non-specific pains in his back and shoulders and uncomfortable tingling sensations in his hands and feet. An MRI of the brain and spinal cord were normal. A lumbar puncture revealed a markedly elevated protein level with sparse mononuclear cells. Nerve conduction studies and EMG were performed and the report is provided.

				Latency (msec)	Amplitude (mV)	C.Velocity (m/sec)
MOTOR NERVE CONDUCTION STUDIES (NR = no response)						
R median	- wrist/elbow	- thenar		13.4	1.1	NR
R ulnar	- wrist/elbow	- hypothenar		8.6	0.9	NR
No increase with exercise						
SENSORY NERVE CONDUCTION STUDIES (NR = no response)						
R median	- wrist/elbow	- index		26.4	5	NR
R ulnar	- wrist/elbow	- index		14.5	10	NR
NEEDLE EXAMINATION				Spont. Activity Fib Fasc Other	Motor Units	Recruitment Pattern
R first dorsal interosseus	+1	0			+ long, normal 66% polyphasic	+ reduced
R abductor digiti minimi	+1	0			normal, +1 tall	+2 reduced
R extensor digitorum communis	0	0			+ long, + tall 33% polyphasic	+ reduced
R biceps	+1	0			normal	+2 reduced
R deltoid	0	0			+2 long, + tall 100% polyphasic	+2 reduced
SUMMARY: Right sensory and motor median and ulnar responses are markedly prolonged in latency and reduced in amplitude. Right ulnar motor response does not increase after exercise. Right ulnar F waves are either profoundly delayed or absent. Needle EMG of right upper limb muscles show reduced recruitment. There is evidence of mild active denervation. MUPs are polyphasic, of increased duration and amplitude.						
INTERPRETATION: There is electrophysiological evidence of severe demyelinating sensory and motor peripheral neuropathy. EMG reveals changes consistent with an acute neuropathic process.						

What is the likely diagnosis? What other confirmatory test could you request?

Answer:

Guillain-Barre Syndrome (Acute Inflammatory Demyelinating Polyneuropathy)

Anti-ganglioside antibody titres (GM-1, GD-1, GQ-1)

Rationale:

A rapidly progressive, ascending weakness with associated sensory features + a mononuclear CSF with elevated protein + normal MRI (i.e. this is not multiple sclerosis) + a demyelinating pattern on the nerve conduction study effectively implies Guillain-Barré syndrome

Question:20

This patient has just had an arterial blood gas performed that revealed a paCO_2 of 50mmHg (6.7 kPa). List 4 possible causes of this scenario?



EtCO_2 33mmHg = 4.4kPa

Answer:

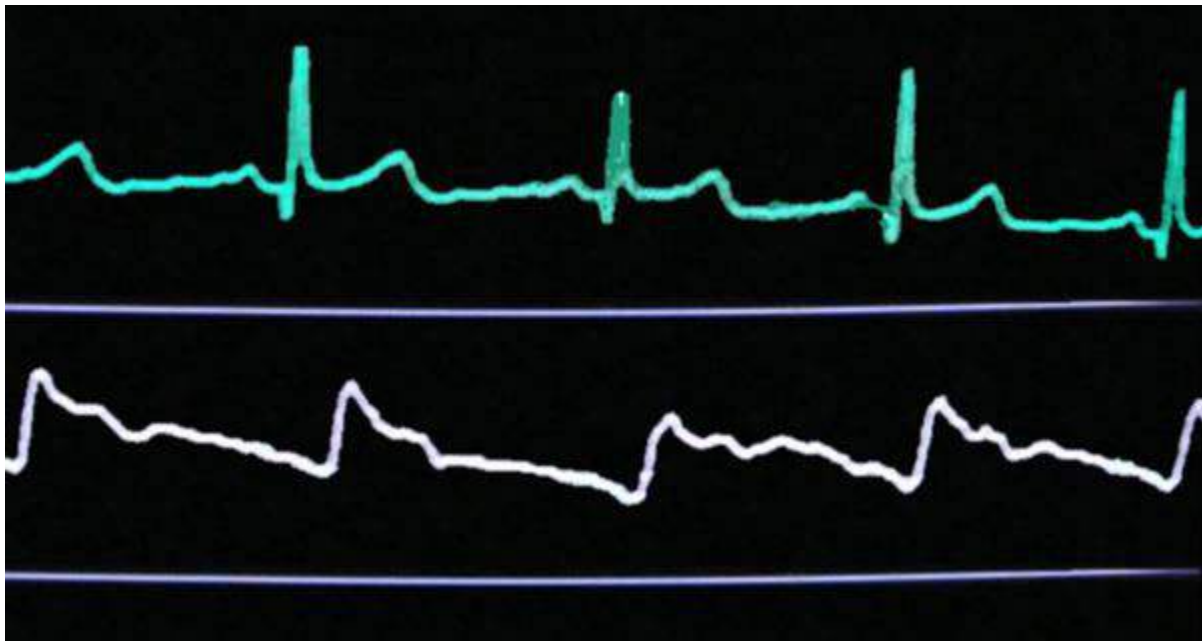
1. Pulmonary embolism
2. Low cardiac output state
3. Emphysema
4. Severe alveolar gas trapping, e.g. severe asthma

Rationale The difference between the EtCO₂ (End Tidal CO₂) and PaCO₂ is usually minimal with the EtCO₂ being slightly lower. This gradient is increased in conditions causing increased alveolar dead space; e.g. high alveolar pressures and/or impaired perfusion states such as massive PE and low cardiac output

Monitoring data – Case 21

Question:

The white waveform shown is of the ICP waveform of a patient with a severe traumatic brain injury. The pressure at this time was 14mmHg. The aim of therapy was <20mmHg. Give 2 reasons why you think the reading is likely to be an accurate reflection of intracranial pressure.

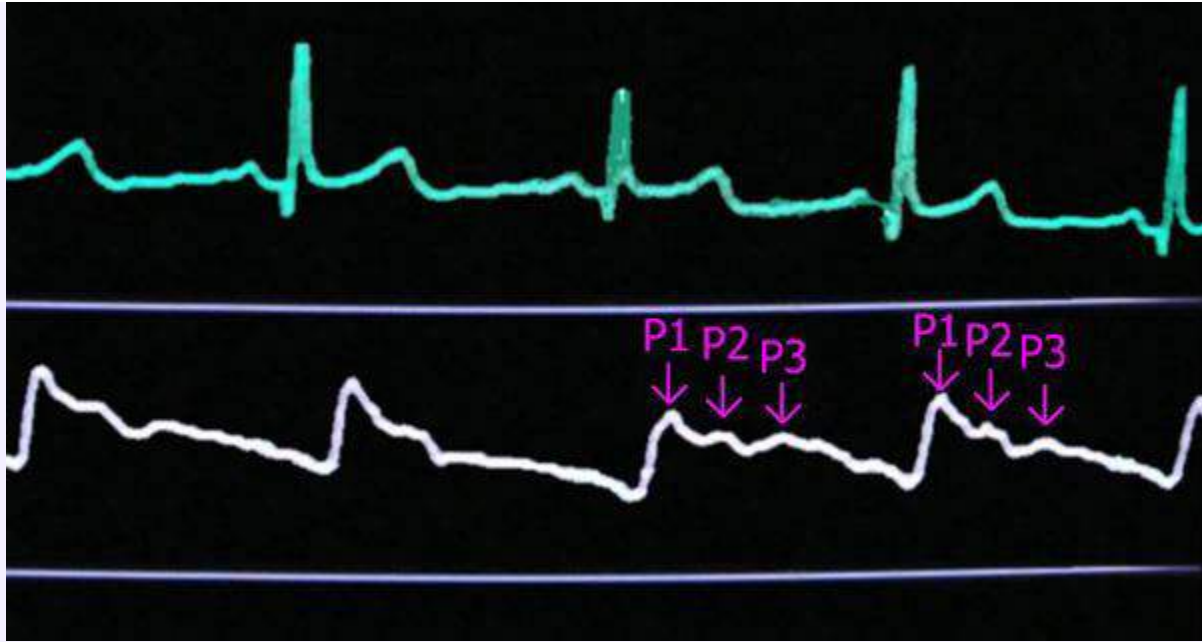


Answer:

A normal non-damped waveform is seen with a clearly visible P1, P2 and P3. If intracranial compliance was poor a prominent P2 would be expected.

Rationale:

See "Chapter supplements", chapter 6 ("Data interpretation"), Table 6.18 and Figure 6.9 for an outline of ICP monitoring.



ICP waveform - Marked.

All of the intensive care specialist examinations (FCICM, EDIC and DCIM) have a strong clinical focus. Your comfort in the clinical environment and familiarity with commonly encountered and critical investigative and therapeutic tools are assessed alongside your knowledge of intensive care. This forms part of the basis for the “Equipment” and “Practical and procedural skills” chapters in the book. The following section of the Recall Cases presents you with some of these important devices and vignettes, which often turn up in both the written and oral components of all three examinations; usually as a means of exploring your wider understanding of intensive care processes. Having a strategy for approaching these questions, is important and can create a great opportunity to sell yourself as an competent specialist, who is at ease in the critical care environment.

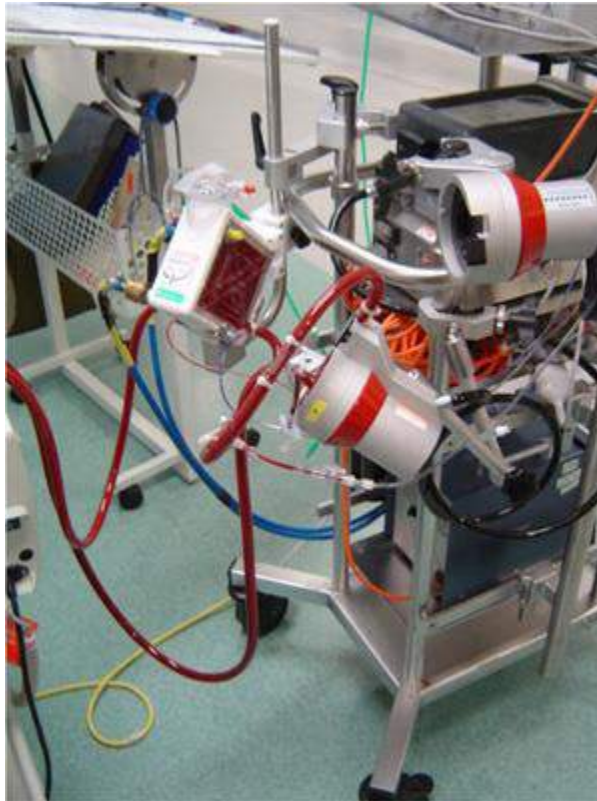
Tips for clinical case based questions.

1. Spend time consciously assessing your own understanding of items and situations that you commonly encounter in your daily practice. It can be quite surprising how many of them you have made assumptions about, or relied on hearsay knowledge without confirming the information. So when you pick up a vial of amiodarone or connect up a 3-chamber pleural drainage set, take a moment to run through its indications, contraindications, procedure, dose, outcomes, complications and evidence. If you find some holes in your knowledge, don't be alarmed, you'll be better prepared for having found them now.
2. Badger your senior colleagues to quiz you about items that are lying around the department or in the store room.
3. Develop your approach to these types of questions. This provides you with a starting point and will often surprise you with how much you can write or talk about a topic that you have not specifically prepared.

Clinical case 1

Question:

List the complications of vvECMO



Answer:

- Bleeding
- Thromboembolism
- Haemolysis
- Cannula insertion complications (e.g. pneumothorax)
- Limb ischaemia
- Infection
- Circuit disruption and exsanguination
- Circuit component failure

Clinical case 2

Question:

This patient returned from theatre 2 hours ago with 50ml of blood in the cardiac drain. You are asked to review them, as the nurse looking after the patient is worried about the drain losses. Are you concerned and why? How does a dry suction chest drain system work?



Answer:

Yes - There is now 800 ml in the drain. This means there has been 750ml in the last 2 hours.

“Dry” suction systems apply suction (e.g. wall suction) that is controlled by a self-compensating regulator adjusted by a dial.

Rationale:

There are various rules of thumb for determining acceptable losses after cardiac surgery. For example more than 400ml in the first hour, 200ml in the second hour and 100ml per hour for subsequent hours should warrant intervention including correction of coagulopathy and urgent surgical review.

With the older “wet” systems, the level of suction is determined by a column of water.

Clinical case 3

Question:

What are the advantages of having this performed over endotracheal intubation?

**Answer:**

In the photograph a percutaneous tracheostomy is being performed using the Cook blue rhino kit™.

Possible benefits include:

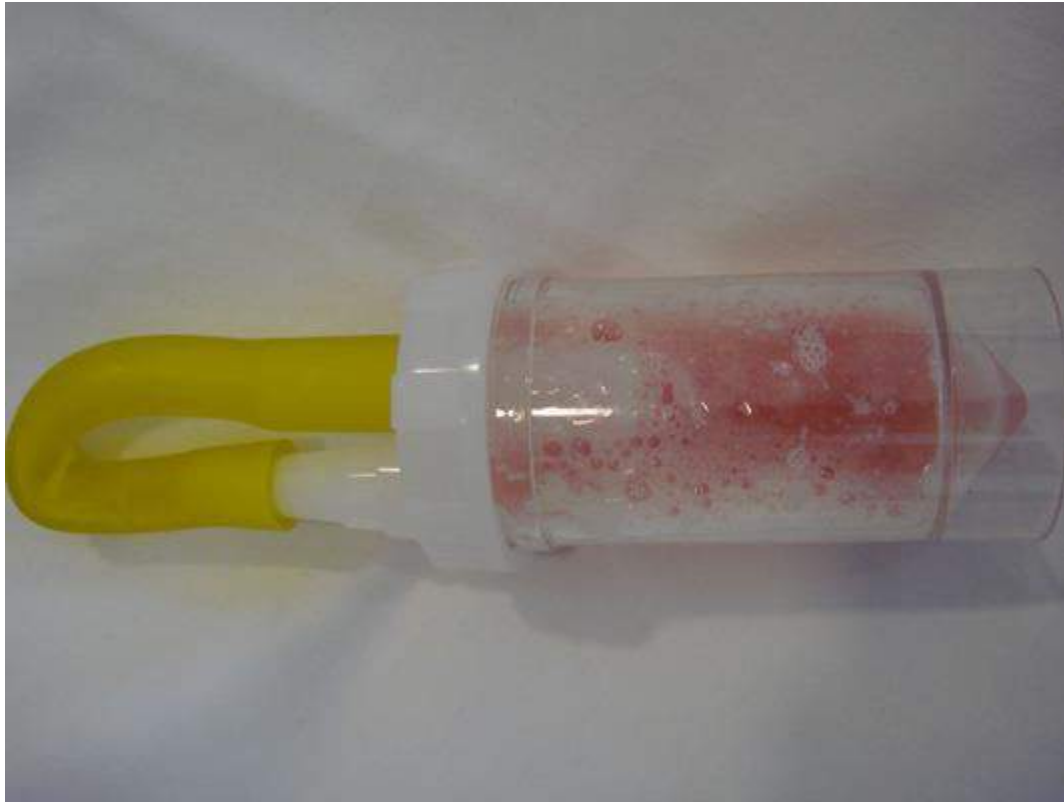
- Reduced risk of upper airway trauma including to the oropharyngeal structures and larynx
- Improved patient comfort including ability to have superior oral hygiene and potential for eating, drinking and phonating
- Reduced requirement for sedation
- Reduced dead space, resistance and work of breathing
- Assists weaning from ventilation

Clinical case 4

Question:

The following sample was taken during suctioning from an endotracheal tube.

List 3 possible causes for this appearance.



Answer:

- pulmonary oedema
- infection
- endobronchial lesions
- pulmonary haemorrhage

Rationale:

The frothy appearance results from air mixed in with blood stained sputum. Blood stained fluid rich sputum can arise from many causes including:

Pulmonary oedema – cardiogenic or non-cardiogenic (the most classic cause of pink frothy sputum)

Other causes of haemoptysis include endobronchial lesions ranging from tumours and vascular lesions to suction catheter trauma, as well as parenchymal pathologies including infection and pulmonary haemorrhage.

Clinical case 5

Question:

You are asked to review this patient, as the nurse is worried that his feet “look terrible”. He was admitted with shock and an intra-aortic balloon pump was inserted. List 4 causes of this clinical appearance.

**Answer:**

1. Vasopressor related vasoconstriction
2. Small vessel emboli (e.g. thrombosis or cholesterol emboli related to the balloon pump insertion)
3. Poor perfusion related to low cardiac output in a patient with peripheral vascular disease
4. Sepsis related small vessel thrombosis

Clinical case 6

Question:

List 3 reasons why this patient's urine may be this colour.



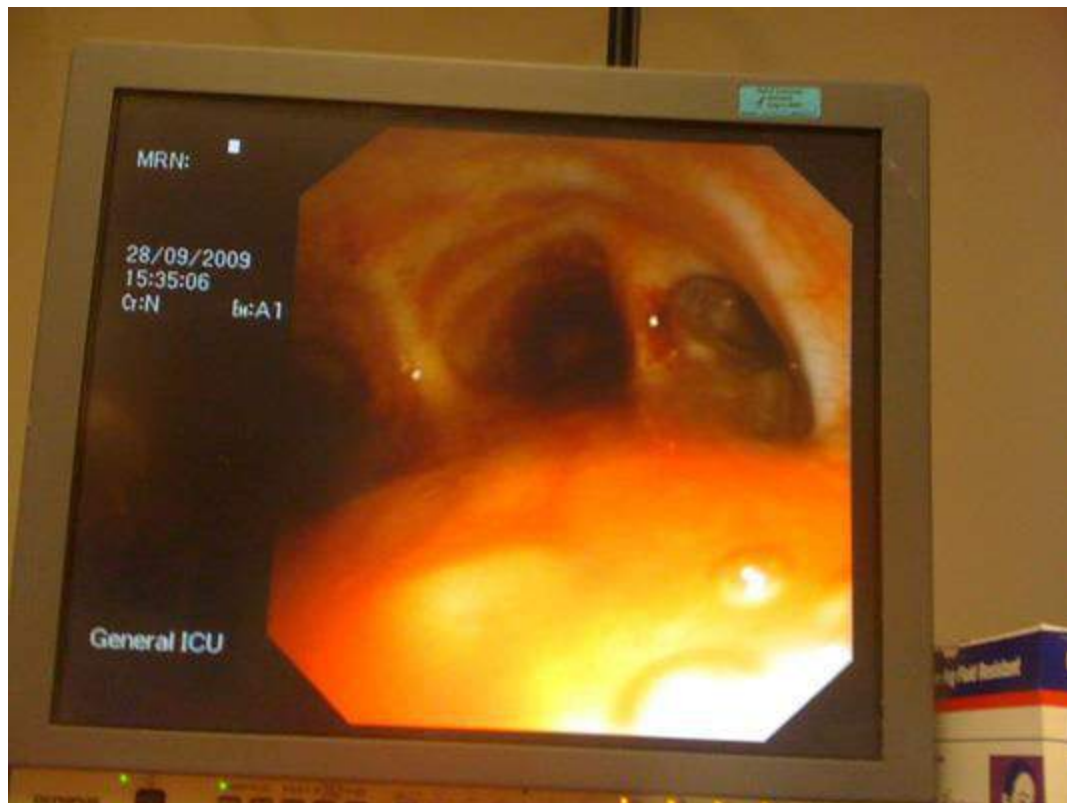
Answer:

- Rifampicin administration (classically orange)
- Rhabdomyolysis (tea coloured)
- Jaundice (dark urine from bilirubin)

Clinical case 7

Question:

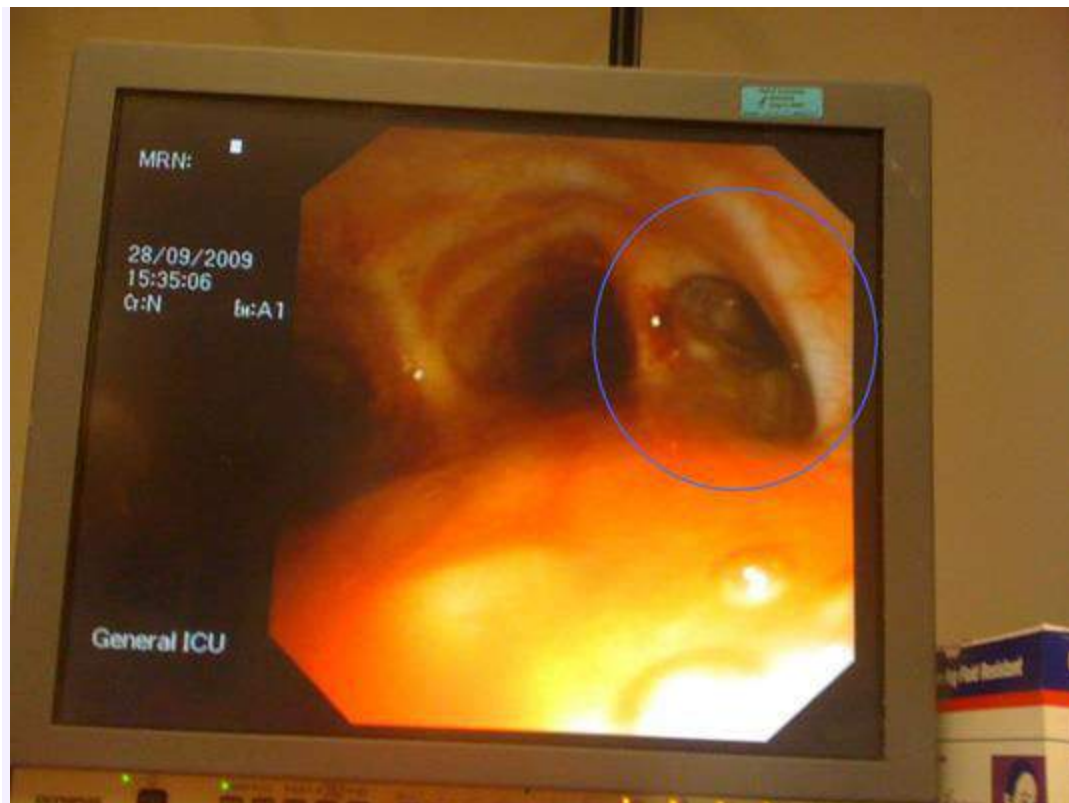
This picture was taken at the time of bronchoscopy for pulmonary toileting in a patient with pneumonia. The view is looking directly at the carina. What common anatomic variant is demonstrated on the image? What is the significance?



Answer:

Aberrant tracheal (right upper lobe) bronchus.

It occurs in up to 2% of patients, may be asymptomatic or associated with recurrent pulmonary infections. It can be occluded by a low lying standard endotracheal or double lumen tube.



Clinical case 8

Question:

This 30-year-old patient with epilepsy attempted suicide by consuming a large quantity of tablets. She developed ventricular tachycardia despite multiple doses of activated charcoal delivered down her nasogastric tube. Extracorporeal therapy with the special filter shown in this image was instituted in ICU. What is this? List 3 specific complications of this therapy. What medication did the patient most likely overdose on?

**Answer:**

A charcoal filter for haemoperfusion is shown.

Complications include thrombocytopaenia, leukopaenia and hypocalcaemia.

In the clinical context carbamazepine is the likely cause of the overdose (although some toxicologists believe high-flux haemodialysis is a reasonable alternative with greater availability)

Clinical case 9

Question:

This 28-year-old patient developed this symmetrical diffuse, blanching rash on the limbs and torso with less involvement of his face and no involvement of the mucosal surfaces. He was febrile with non-specific abdominal pain, painful joints and myalgia. The day after admission the rash appeared more purpuric. He had been commenced on amoxicillin 8 days previously by his GP for a "sore throat". He was admitted to the HDU for observation. Name 2 possibilities for this clinical picture.

**Answer:**

1. Drug eruption – leukocytoclastic vasculitis
2. Reaction to amoxicillin in acute EBV infection

Clinical case 10

Question:

This 50-year-old man was admitted to ICU with acute renal failure requiring renal replacement therapy. He had bilateral alveolar infiltrates and a recent history of “sinus problems”. He had the following rash noted, predominantly on his limbs. A skin biopsy demonstrated neutrophils and giant cells. What is the likely diagnosis?

**Answer:**

Wegener's granulomatosis

Rationale:

Wegener's granulomatosis is a small vessel, ANCA positive (anti-PR-3) vasculitis that classically affects the upper and lower respiratory tract and the kidneys. The diagnosis is often delayed, as the patient is frequently diagnosed as having recurrent sinusitis.

Clinical case 11

Question:

List 3 potential uses for this product in the ICU setting.

**Answer:**

Anaesthesia of the nasal mucosa for nasogastric tube passage

Anaesthesia of the upper airway to facilitate bronchoscopy

Anaesthesia of the upper airway to facilitate intubation

Clinical case 12

Question:

A 17-year-old, 35kg woman was admitted with severe electrolyte derangements, complicating long-standing anorexia nervosa. The following enteral nutrition is being delivered on day 2. List 3 methods for determining her caloric needs. What would be your target-feeding rate for this patient using this feed? What complication would you be most worried about?



Answer:

Methods of estimating caloric needs include:

- Empiric calculation (e.g. 25-35kCal/kg/day)
- Use of predictive equations (e.g. Harris Benedict, Schofield)
- Indirect calorimetry

Using an empiric calculation the target rate would be

(30kCal x 35kg = 1500kCal; using 1kCal/ml feed pictured this would mean approximately 40ml/hr)

This patient is at high risk of developing refeeding syndrome. Frequent PO_4^{3-} measurement will be required for early detection of hypophosphataemia.

Clinical case 13

Question:

Concern is raised by a bedside nurse that she is having difficulties suctioning down a patients endotracheal tube. What is the possible significance of this?



Answer:

Tube obstruction is the likely cause of this observation and this may herald airway obstruction.

Causes are extraluminal (e.g. tube kinking or occlusion from biting), intraluminal (e.g. secretions or blood) or malposition (e.g. abnormal positioning against the carina if too far in or at the vocal cords if too far out).

It warrants urgent clinical review. In anaesthetic practice the DOPE drill is used – Displacement / Obstruction (Intra / Extraluminal) / Patient / Equipment

Clinical case 14

Question:

a) List 4 indications for these medications in ICU.



b) A 36-year-old asthmatic patient is receiving a cisatracurium infusion to facilitate her ventilatory therapy. How would you use this piece of equipment to assist in her management?



Answer:

a) Indications include:

1. To facilitate translaryngeal intubation
2. To facilitate mechanical ventilation
3. To reduce muscular activity to reduce basal metabolic rate (e.g. if refractory raised intracranial pressure)
4. To facilitate therapeutic hypothermia by preventing shivering

b) A 'train of four impulse' is applied and four equal thumb 'twitches' (from adductor pollicis activation) are expected if conduction is fully intact. A fade response with only 2-3 twitches being detectable is a commonly prescribed end-point.

(The optimal monitoring of continuous neuromuscular blockade is controversial although use of a nerve stimulator is commonly recommended over clinical methods, titrated to levels that just prevent movements. An electrical impulse is applied to a peripheral nerve (e.g. median nerve) that is transmitted to the neuromuscular junction and translated into visible muscular movement, as long as the neuromuscular junction is intact.)

Clinical case 15

Question:

Isolation rooms in the ICU may be designed to produce environments of positive, negative or neutral air pressure.



What are the indications for using each of these settings?

Answer:

Positive pressure (greater supply of air than can effectively be contained by the room, through a constant supply of approximately 110% of the volume of the room, leads to air flowing from the room to outside areas of the ICU. Keeps harm outside the room.) – commonly used for immunosuppressed and burns patients

Negative pressure (greater exhaust volume through the venting system than can escape by other routes leads to the drawing of air into the room ; the air exhausted outside the area is filtered before being returned to the ICU environment. Keeps harm inside the room.) – used for patients with diseases spread by airborne droplets (e.g. TB, Influenza, Neisseria meningitides, VZV, Measles, Pertussis, Smallpox) or other potentially transmittable airborne fumes (e.g. severe organophosphate poisonings with noxious fumes)

Neutral pressure (equal exhaust and supply air) – standard care for other patients

Clinical case 16

Question:

a) What procedure is being demonstrated in this image?



b) The following images show the effects of the transducer being located too high, too low and at the appropriate point relative to the phlebostatic axis zero point on a patient who had an elective cervical decompression for cervical spondylosis last night and is progressing well. Assuming that the non-invasive blood pressure reading is accurate and was just performed, which image do you think relates to which scenario?

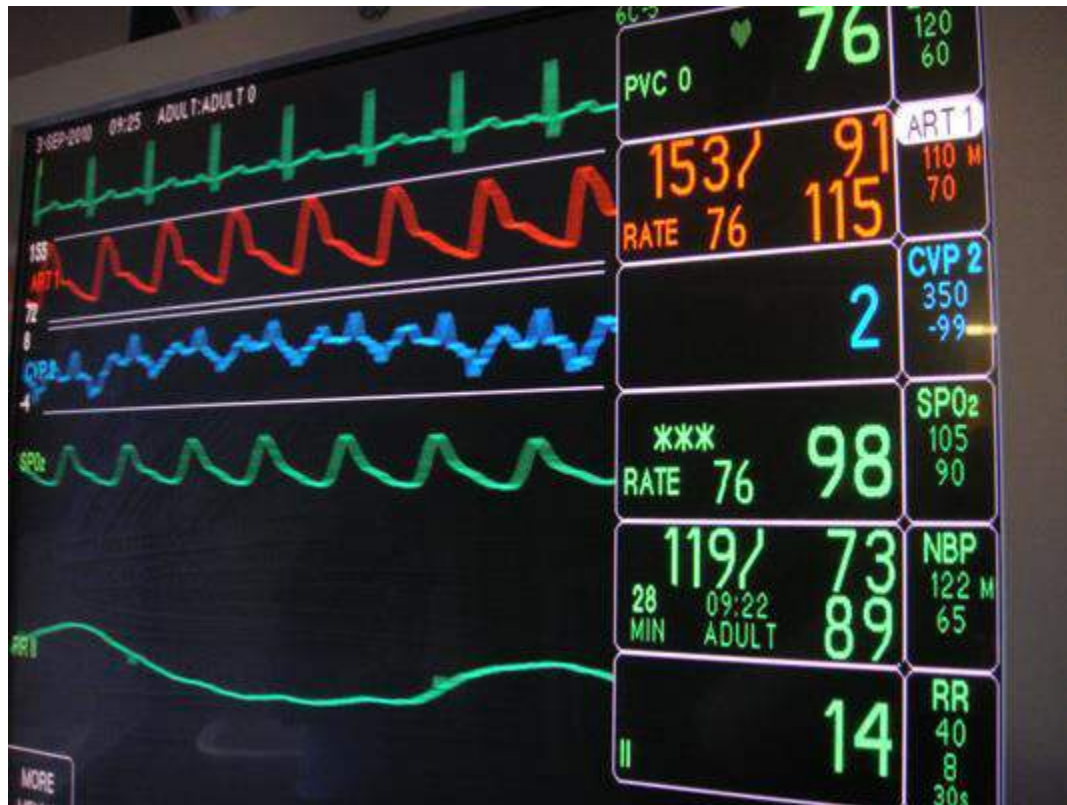
(A)



(B)



(C)



Answer:

a) A carpenter's spirit level is seen and in the ICU context, being used to ensure a pressure transducer is leveled at the appropriate level (ie. phlebostatic axis/mid-axillary line).

b) A - appropriate level

B - transducer too high

C - transducer too low

Question:17

What do you think of the damping of the system based on the fast flush test seen in this image?



Answer:

The image shows an undershoot followed by a small overshoot that rapidly settles into the patient's waveform. This is consistent with optimal damping.



Clinical case 18

Question:

List 3 indications for using therapeutic hypothermia in the ICU?



Answer:

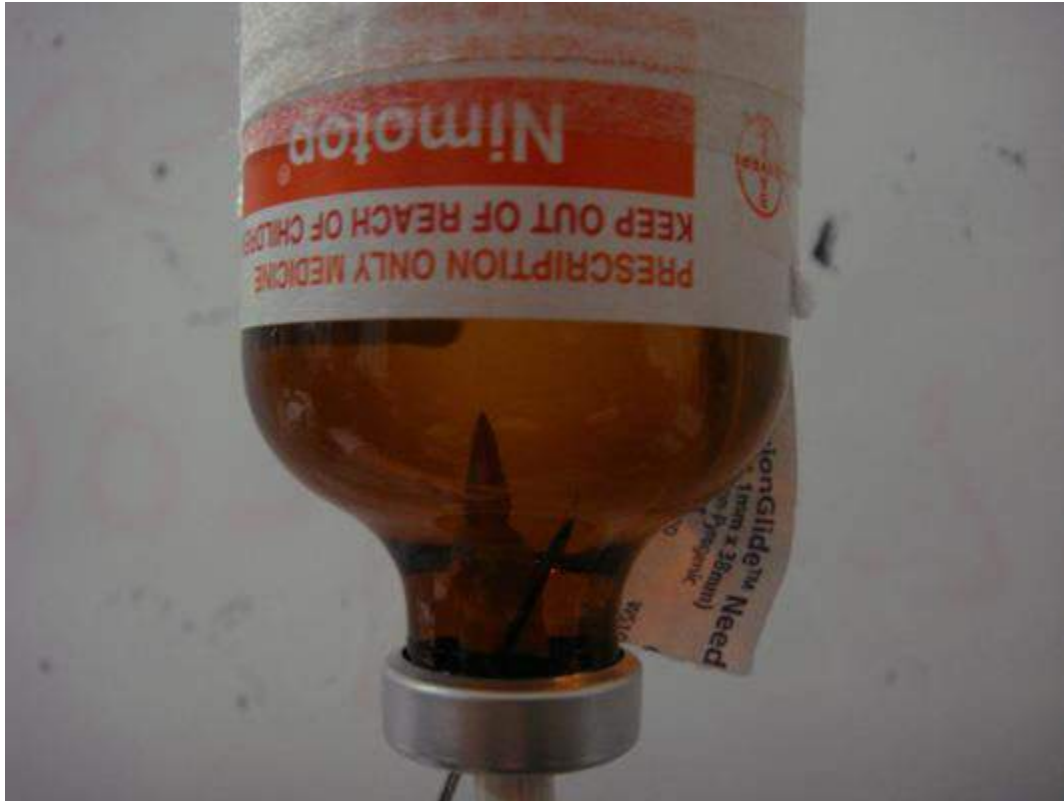
As an adjunct for managing severe hyperthermia emergencies (e.g. heat stroke, malignant hyperthermia, serotonin syndrome, neuroleptic malignant syndrome)

As a therapy to improve neurological outcome after out of hospital cardiac arrest (especially ventricular arrhythmias)

As a therapy for refractory raised intracranial hypertension; e.g. reduce basal metabolic rate

Question:19

A 39-year-old woman was admitted with a grade 2 sub-arachnoid haemorrhage. Her digital subtraction angiogram did not show an aneurysm. The neurosurgical team has asked you to commence nimodipine. What is the evidence for this therapy in this situation?



Answer:

Studies of oral nimodipine in aneurysmal sub-arachnoid haemorrhage suggest that compared to placebo it improves survival and reduces the rate of cerebral infarction due to vasospasm. There is also a suggestion, following a metanalysis, that a combination of 7-10 days of intravenous nimodipine followed by 2 weeks of oral nimodipine may reduce ischaemic complications. However, the evidence is moderate and it remains a controversial area

Clinical case 20

Question:

A patient is about to be connected to the ventilator. What form of humidification is being used in the circuit pictured?



Answer:

A 'wet' circuit is demonstrated.

Rationale:

There is no HME(F) at the interface covered with the glove (some units use a rubber stopper rather than a glove) that will be connected to the patient's endotracheal tube (need an arrow in the image) and a blow-by water bath humidifier (pink arrow) is seen underneath the ventilator control panel. Two types of HME (yellow arrows) can be seen at the interfaces where the ventilator inspiratory and expiratory limbs of the circuit are attached to the ventilator. The filter on the expiratory limb is not being used for its humidification feature, rather it is placed to minimise the transmission of organisms from the patient to the ventilator. Many intensivists would acknowledge that a HMEF is not strictly necessary for the inspiratory limb, as the gas flow would largely prevent retrograde movement of organisms or other material back into the machine; nonetheless, many units still place one here.



Yellow arrows = HME

Pink arrow = blow by water bath humidifier

Clinical case 21

Question:

A ventilated patient with severe community acquired pneumonia developed a sudden onset of the following diffuse rash associated with wheeze and worsening hypotension. Describe the appearance. What is the most likely cause of this? List 5 treatments.



Answer:

There are wheals present, lesions that appear raised with erythematous margins. The clinical picture is suggestive of anaphylaxis.

Management would therefore include:

1. Ceasing possible causative agents (e.g. drugs, commonly antibiotics)
2. Adrenaline bolus of 300mcg IM
3. Oxygen via NRBM to achieve SpO₂ > 96%
4. Fluid resuscitation
5. Corticosteroid, e.g. hydrocortisone 200mg IV

Others adjuncts that are used include:

1. H1 antagonists (antihistamines such as promethazine)
2. H2 antagonists (e.g. intravenous ranitidine)

Clinical case 22

Question:

This patient was receiving intravenous infusions of fentanyl and propofol. Midazolam was added and the nurse instructed to wean off the propofol as the Intensivist was worried about giving prolonged high dose propofol. Why were they concerned?



Answer:

Infusions of high doses of propofol ($>4\text{mg/kg/hr}$) for >24 hours has been associated with Propofol Infusion Syndrome (PIS). Features of PIS include metabolic acidosis, rhabdomyolysis, renal and cardiac failure and death. This has been documented in a range of ICU populations, particularly children and young head injured patients.

Clinical case 23

Question:

The following signs were observed during clinical bedside case examinations. What is the likely significance of noting these two findings?



Answer:

“NO ECM” is short for “No External Cardiac Massage” and usually suggests that the patient has an open sternum, usually as a result of complicated cardiac surgery where bleeding and/or severe right ventricular dysfunction were problematic.

“NO BP taking in this arm” suggests that the patient has either had axillary node clearance (e.g. previous breast cancer surgery) or has an arteriovenous fistula and is a chronic dialysis patient. In this case there is a raised protrusion that looks like a vascular dilatation consistent with a fistula.

(Signs such as these must not be missed as they are important clues to underlying acute and chronic problems and pathologies.)

Clinical case 24

Question:

Two different antidotes are seen in the following image. What are they used to treat? Identify one major problem associated with using each of these.



Answer:

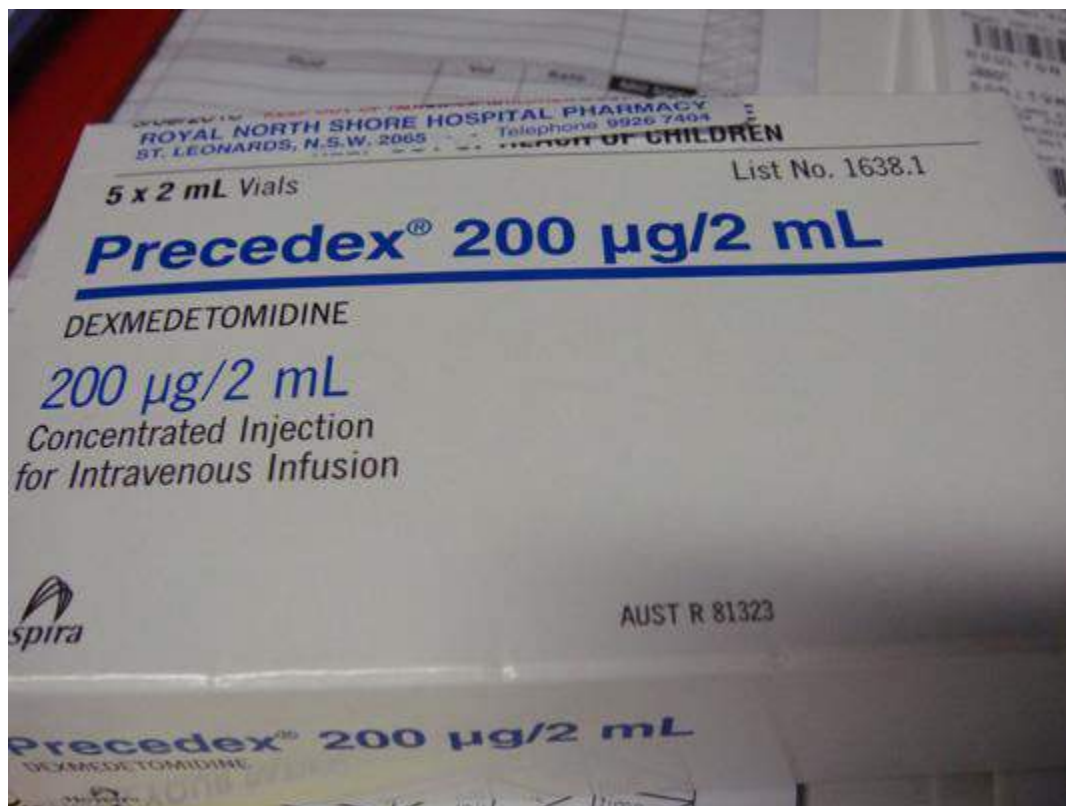
Naloxone is used to treat opioid overdose. It has a short half-life, which means there may be a life-threatening rebound effect. In patients with accidental overdoses, reversal may trigger severe pain in patients receiving opioid analgesia.

Flumazenil is used to treat benzodiazepine overdose. A rebound effect may also be seen when used to treat long acting benzodiazepine toxicity. Most worryingly it can trigger seizures if used in the scenario of polypharmacy overdose with agents lowering the seizure threshold, particularly tricyclic antidepressants

Clinical case 25

Question:

How does this drug work? What are the associated pharmacodynamic effects?



Answer:

Dexmedetomidine is a centrally acting alpha-2 agonist. The pharmacodynamic effects resemble clonidine and include sympatholysis with bradycardia and hypotension, sedation, analgesia and anxiolysis without respiratory depression.

Its role in Intensive Care practice remains to be fully elucidated although it is most commonly used for perioperative sedation and may have beneficial effects over other groups of commonly used agents such as benzodiazepines (SEDCOM and MENDS trials).

Clinical case 26

Question:

The following drug may be used to induce prolonged therapeutic coma. Name three conditions where patients may benefit from this therapy and state the endpoints for the therapy in these scenarios. List 4 complications of this



therapy.



Answer:

Thiopentone coma is a controversial therapy that may be used for patients with status epilepticus unresponsive to standard, less toxic therapies and patients with refractory raised intracranial pressure after traumatic brain injury. In these circumstances it is titrated to the lowest rate that controls seizures or pressure (e.g. less than 20mmHg). Some centres also use thiopentone coma to manage the neurological consequences of severe cerebral vasospasm by reducing cerebral metabolic demand (e.g. following a severe subarachnoid haemorrhage) with an end point of achieving burst suppression.

Potential complications include hypotension, immunosuppression with life-threatening nosocomial infections (especially VAP), hypokalaemia (with rebound hyperkalaemia if potassium is replaced to normal levels during coma), pupillary dilatation and loss of the light reflex with burst suppression that may be difficult to distinguish from brain death and delay its diagnosis.

Of note, thiopentone is soon to be withdrawn from the market and will no longer be produced by the manufacturer, as notified to the FDA on the 25th of January 2011.

Clinical case 27

Question:

Two variants of a structure used for electrical safety in ICU bedspaces are pictured. What are these green devices and what is their function?



Answer:

These *earth points* prevent microshock in cardiac protected areas where patients have devices with a direct path to the heart (e.g. pacing wires, central lines, pulmonary artery catheters).

Additional information

All equipment must be preferably CF (Cardiac Floating) in the bedspace (ie. designated to produce ultralow leakage currents that do not represent a risk to the patient). If non-CF devices are used in the bedspace (e.g. on trolleys such as TV sets) they are attached to the green lugs so any leakage of current flows to these ultralow resistant earthing points instead of into the patient if a connection is made between the patient and the device (e.g. via a staff member).

Clinical case 28

Question:

Question

- a) How is this agent thought to lower intracranial pressure?
- b) Why might it be less effective than hypertonic saline for this purpose?
- c) What is the recommended dose of the preparation pictured?



Answer:

- a) Mannitol may lower intracranial pressure by acting as a powerful osmotic agent facilitating extracellular fluid loss of water and sodium and thus reducing cerebral oedema. An earlier beneficial effect may be an increase in intravascular blood volume, thereby improving the rheology of blood flow and enhancing cerebral perfusion.
- b) There are increasing concerns that in high doses it may worsen cerebral odema by passing across a non-intact blood-brain barrier and “pulling” fluid into the brain. There are, however, other theories on its actions, including effects on both the damaged and undamaged portions of the brain which may result in local neuronal injury. Hypertonic saline may therefore be a superior agent for osmotherapy for intracranial hypertension (e.g. 3% saline).

c) A commonly used dose for an acute crisis is 0.25-1g/kg. The pictured 500ml bag of 20% mannitol contains 100g or (20g per 100ml). Therefore for an 80kg adult, 20-80g are needed, equivalent to 100-400ml.

Question:29

This patient was admitted to ICU with 60% total body surface area burns after being trapped in a house fire. The burns involved predominantly his head and torso. List 6 clinical findings that would raise your suspicion that this patient had experienced an inhalational injury.



Answer:

1. facial burns
2. singed nasal vimbrissae
3. carbonaceous respiratory secretions
4. hoarse voice
5. stridor, wheeze
6. respiratory distress

Additional aspect

This question may alternately be posed as "What cause of hypoxia might you be suspicious of and why?"

Answer:

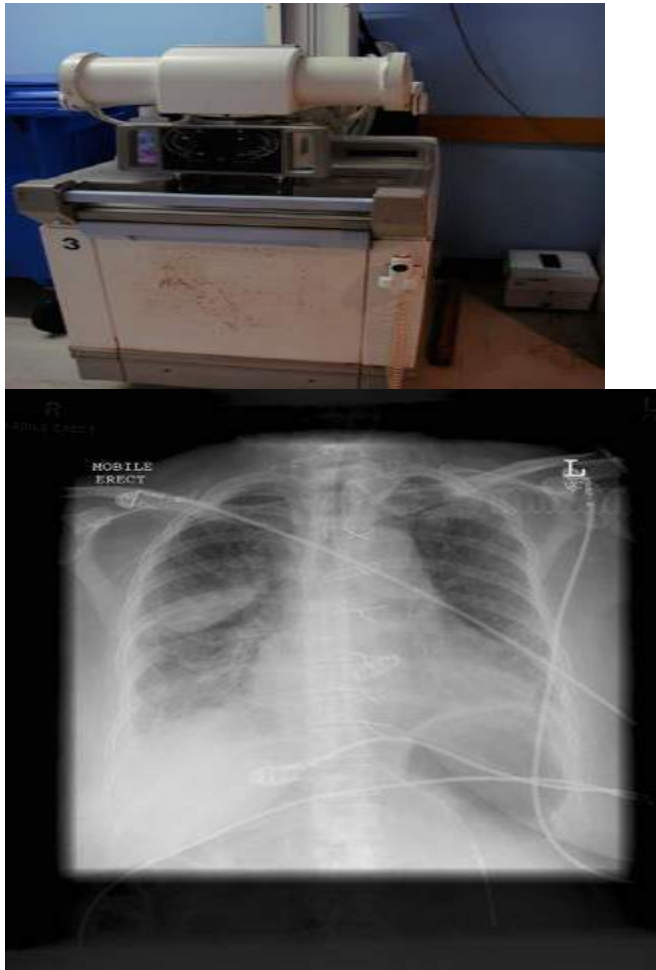
Carboxyhaemoglobinaemia (CO-Hb)

- History – trapped in a confined space with poor ventilation
- Investigations – ABG showing impaired gas exchange, unexplained lactic acidosis (suggesting accompanying carbon monoxide and/or cyanide toxicity. Modern ABG machines usually provide a CO-Hb and Met-Hb level)

Clinical case 30

Question:

Portable chest x-rays are commonly performed in ICU patients daily. What is the evidence supporting this activity?



Answer:

This has been a periodically discussed topic in the critical care literature and remains a controversial topic. Most recently a meta-analysis analysed eight studies involving 7078 patients that compared on-demand with unselected routine daily chest x-rays. They found that there was no difference in ICU or hospital mortality, length of stay or ventilator days. Regression analysis did not identify a subgroup of patients who might benefit from daily routine x-rays although one might exist.

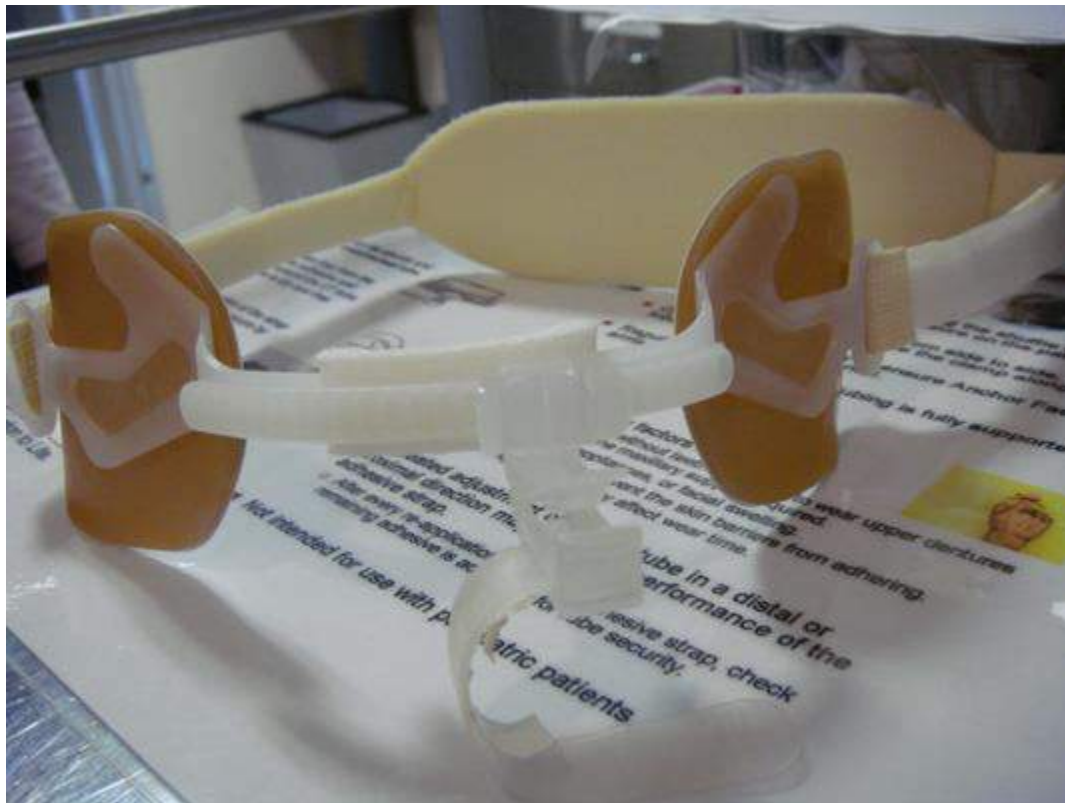
Oba Y, Zaza T. Abandoning Daily Routine Chest Radiography in the Intensive Care Unit: Meta-analysis. Radiology. 2010; 255; 386-395.

Clinical case 31

Question:

A Hollister endotracheal tube attachment device™ is pictured. It has a sliding section that enables the tube to sit and be repositioned securely at different locations on the lip to avoid pressure areas. It has adhesive sections that attach firmly to the skin but also form a protective skin barrier. It has replaceable side straps that can be substituted if soiling occurs.

What criteria would you use to evaluate the product in your ICU prior to purchasing it?



Answer:

One approach would be to consider the following topics:

- Ease of application and need for education in use
- Recommended duration of use before needing replacement
- Comparison to existing tube securing devices – are there better new products now available?
- Feedback (medical and nursing) from a clinical trial period (e.g. 5-10 cases); will the company supply trial samples for free?
- What has been the experience of other departments that have used it?
- Is the device readily available in the desired quantities? (e.g. are they an existing hospital preferred contractor)
- Are there greater competing priorities for using available resources within the unit?

- Is the device compatible with the equipment that is currently in use in the department and, if necessary, across the hospital?
- Cost – individual unit prices for the device and the replaceable straps; are special price deals available for large orders? Is the quoted price a special introductory deal that will increase later?

(Note - Questions may arise in examinations that may not have been specifically prepared for and a logical approach is expected based on clinical experience and common sense.)

Clinical case 32

Question:

A 65-year-old man received ifosfamide as part of his sarcoma chemotherapeutic regimen. The day after therapy he became progressively confused and drowsy and then had a generalised seizure. He was intubated and ventilated in the ICU and remains combative when propofol sedation is lightened. Could this scenario be associated with his chemotherapy? If so what is the most likely mechanism and what is the treatment?



Answer:

Ifosfamide is an alkylating agent used to treat a range of cancers including sarcoma, gynaecologic and testicular tumours as well as lymphomas.

Ifosfamide is classically associated with encephalopathy that may occur up to 2 days after it is administered and typically lasts for up to 3 days. There is no clear dose-response. Low serum albumin may be a risk factor. Clinical features range from dizziness, mood and behavioural changes to mutism, extrapyramidal signs, confusion, seizures and coma.

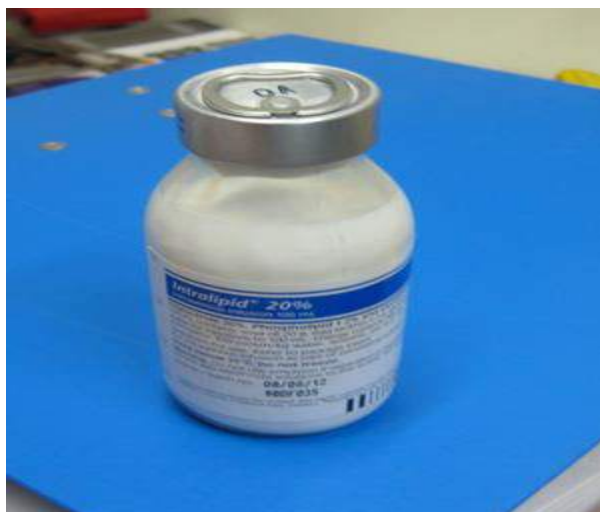
Ifosfamide encephalopathy may be related to the effects of chloroacetaldehyde, an active metabolite that crosses the blood brain barrier. Methylene blue appears to be an “antidote”. The precise mechanism remains unclear although it may reduce the formation of the metabolite and/or attenuate its effects. It is now used prophylactically.

Pelgrims J, De Vos F, Van den Brande J, Schrijvers D, Prove A, Vermorken J. Methylene blue in the treatment and prevention of ifosfamide-induced encephalopathy: report of 12 cases and a review of the literature. Br J Cancer. 2000; 82; 291-294.

Clinical case 33

Question:

A 26 year old lady is brought to the emergency department with bradycardia, hypotension and a decreased level of consciousness. An empty packet of metoprolol was found near her, with a label on it that indicated it had been dispensed yesterday. An adrenaline bolus is given with no effect and she is intubated. List 3 modes of therapy for her suspected β -blocker toxicity, other than the one shown in the picture. Outline the proposed mechanism for the therapy shown in the picture.



Answer:

Therapeutic options

1. Adrenalin infusion
2. IV Glucagon
3. Temporary pacing, transcutaneous or transvenous

Intralipid is thought to act as a lipid sink, reducing the bioavailability of lipid soluble agents and thereby reducing their toxic effects in overdose. It was originally introduced in anaesthesia for the reversal of local anaesthetic induced cardiotoxicity, but its use has been extended to other lipid soluble drugs. While few RCTs have been conducted outside of local anaesthetic toxicity animal studies, registries of case reports have been set up in several countries to document the use of intralipid rescue, with all of the caveats that this entails. The optimal dose has not yet been established, though a bolus of 1.5ml/kg 20% intralipid with a subsequent infusion at 0.25ml/kg/min, to a total maximum of 8ml/kg has been proposed by Dr. Guy Weinberg, who has performed the majority of the animal trials and runs www.lipidrescue.org

Picard J, Meek T. Lipid emulsion to treat overdose of local anaesthetic: the gift of the glob (editorial). *Anaesthesia* 2006;61:107-9

Weinberg GL, Ripper R, Feinstein DL, Hoffman W. Lipid emulsion infusion rescues dogs from bupivacaine-induced cardiac toxicity. *Reg Anesth Pain Med*. 2003; 28:198-202.

Clinical case 34

Question:

A 56-year-old man was admitted to ICU overnight, from the ward with respiratory failure. He was admitted to hospital 6 days ago with a diagnosis of community acquired pneumonia. His chest x-ray suggested bilateral pleural effusions were present and bilateral small bore drains have been inserted with an ultrasound guided Seldinger technique. The following specimens were obtained:



Right chest



Left chest

a) The bedside nurse has run a sample of each through the blood gas machine on the ICU and the following results are available:

	Blood gas 1	Blood gas 2
pH	7.603	6.372
Glucose	10.1	0.0
Lactate	2.3	22
Hb	0.6	0.1
paO ₂	162	37.6
paCO ₂	30.2	216

Which specimen do you think belongs with each result and why?

b) Only one of the specimens has reached the laboratory. The following results are available:

Serum biochemistry taken at time of drainage procedure:

Protein 37 g/L

LDH 158 U/L

Pleural fluid:

Protein 51g/L

LDH 7560 U/L

Which specimen do you think these results are from and why?

Answer:

a) Blood gas 1 is from the right chest and blood gas 2 from the left chest. The specimen from the right side looks haemoserous and non-turbid. The specimen from the left side looks purulent and the results suggest an empyema is present with an acidic pH, very high lactate and absent glucose.

b) The results are consistent with an exudate and therefore most likely from the left chest with an empyema. This is a well-described complication of pneumonia.

Pleural fluid: serum protein = $51/37 = 1.4$ (>0.5 defines an exudate by Light's criteria)

Pleural fluid: serum LDH = $7560/158 = 47.9$ (>0.6 defines an exudate by Light's criteria)

Tips for paediatric recall cases

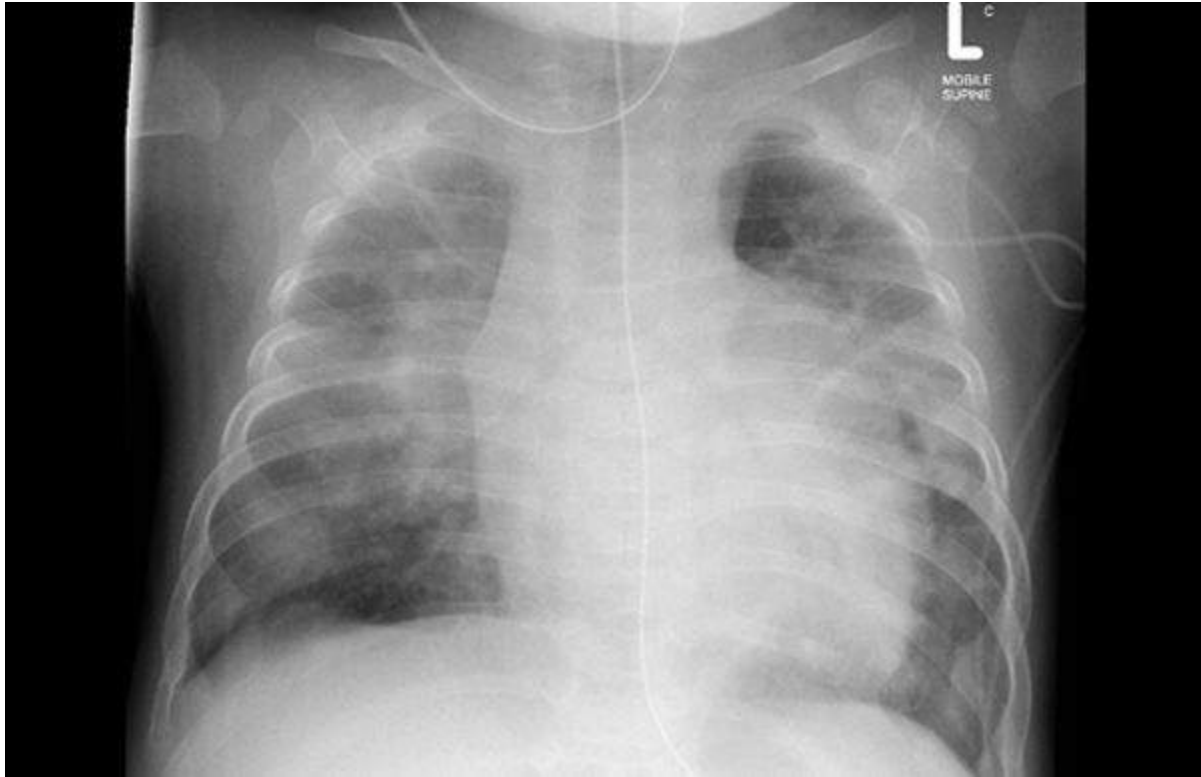
1. The list of possible diagnoses for the exam is relatively small.
2. The same principles as for adult recall cases apply in terms of the approach to the different types of question.
3. Reference to the Key Paediatric Facts table in chapter 10 will aid answering questions where some knowledge of basic paediatric equations and principles are needed.

Paediatric Case 1

Question:

This 5 month old boy was brought to the ED by their mother. She said he had had fevers and was feeding poorly. On examination he has a respiratory rate of 60 and obvious respiratory recession. This is his CXR on admission to PICU.

What is the most likely diagnosis and what is the usual pathogen?

**Answer:**

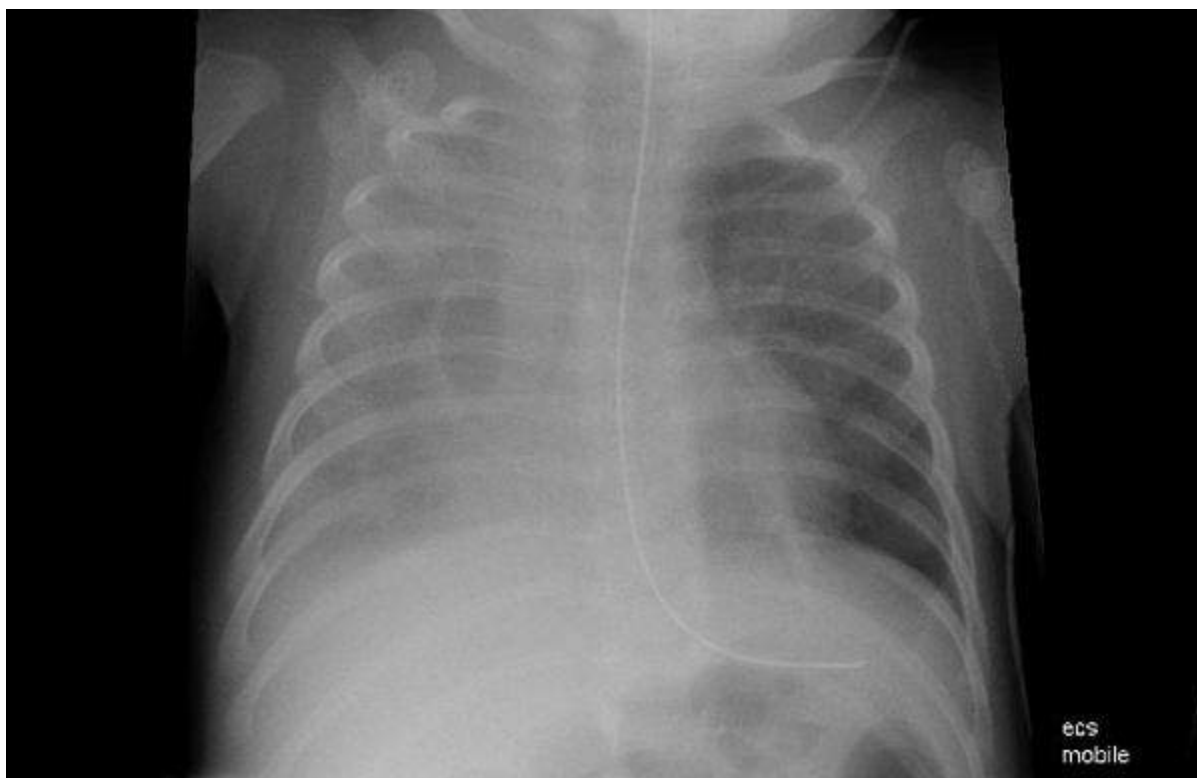
The diagnosis is bronchiolitis and respiratory syncytial virus (RSV) is isolated in approximately 75% of children, from naso-pharyngeal aspirates. Other causes include parainfluenzae virus types 1, 2, 3, influenza virus and adenovirus.

The CXR is usually not needed for the diagnosis but typically shows hyperinflation, with flattened diaphragms and air trapping. As in this x-ray there may be lobar infiltrates and atelectasis especially in the upper lobes.

Paediatric Case 2

Question:

This 1 month old child presented with meningitis 7 days ago and has been ventilated in the PICU since admission. He has been increasingly difficult to oxygenate overnight and this is his CXR. Describe the main findings and suggest a diagnosis.



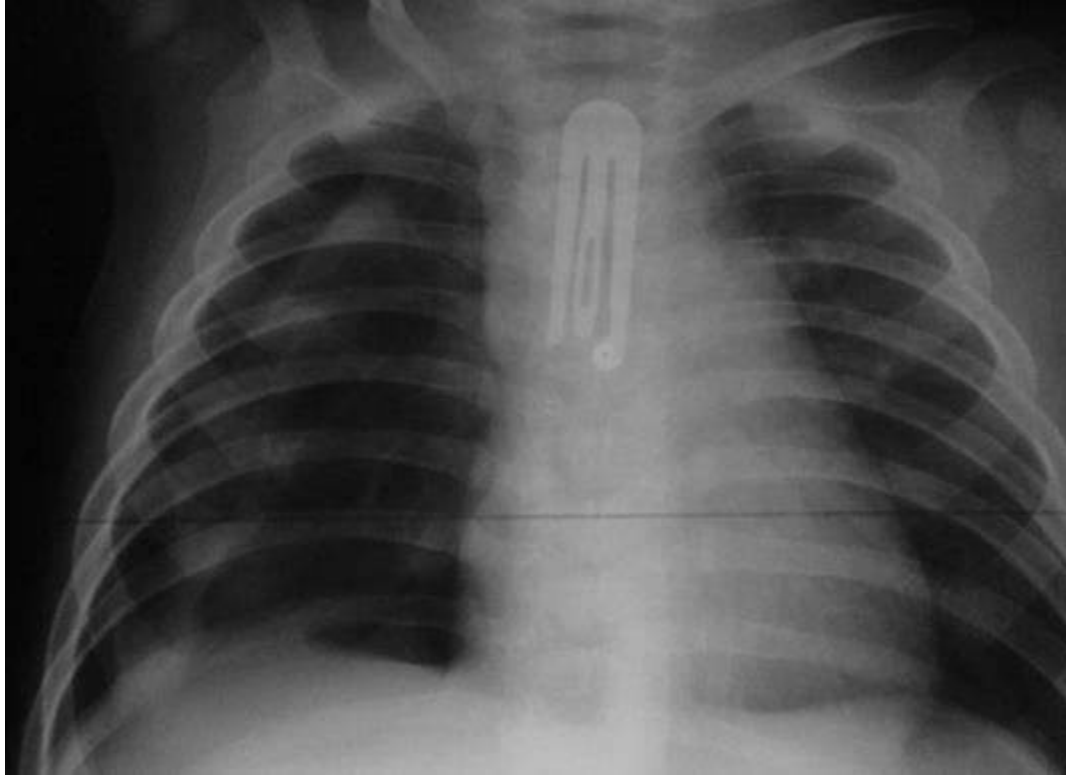
Answer:

Right sided consolidation with collapse suggesting infection. Intubated with NG tube in situ.

Paediatric Case 3

Question:

This 3 year old boy was found by his mother dribbling and looking distressed. In ED he appeared slightly distressed but there were no other abnormalities on examination. What is the main finding on his CXR and what would be your initial management plan?



Answer:

There is an obvious foreign body which looks like a hair clip. There is no obvious perforation seen on the plain film. Management priorities would include removal of the foreign body under general anaesthesia and repair of any perforation, with consideration of antibiotic coverage given the risk of mediastinal involvement.

Paediatric Case 4

Question:

This premature baby has been in NICU for the last 5 days. You have been asked to review them as the nursing staff have noticed that the abdomen appears distended and the baby has started vomiting. You examine the baby and then arrange an AXR. Describe the main abnormalities and suggest the most likely diagnosis.



Answer:

The AXR shows gas in the bowel wall. Gas is also sometimes seen in the portal venous system or as free gas in the peritoneum. The diagnosis is necrotising enterocolitis.

This condition is predominantly seen in premature infants and carries a mortality of 30-40%. The cause is unclear but it usually occurs in enterally fed babies. Management is supportive and may involve inotropes and ventilation, with cessation of enteral feeds and use of TPN. Broad spectrum antibiotics are given and the babies need to be observed carefully for perforation.

Paediatric Case 5

Question:

This 6 month old had this AXR done in the ED after presenting with dehydration and bloody diarrhoea. She also appeared to be in pain with in drawing of her legs and obvious distress. List the two most likely diagnoses in order of probability.



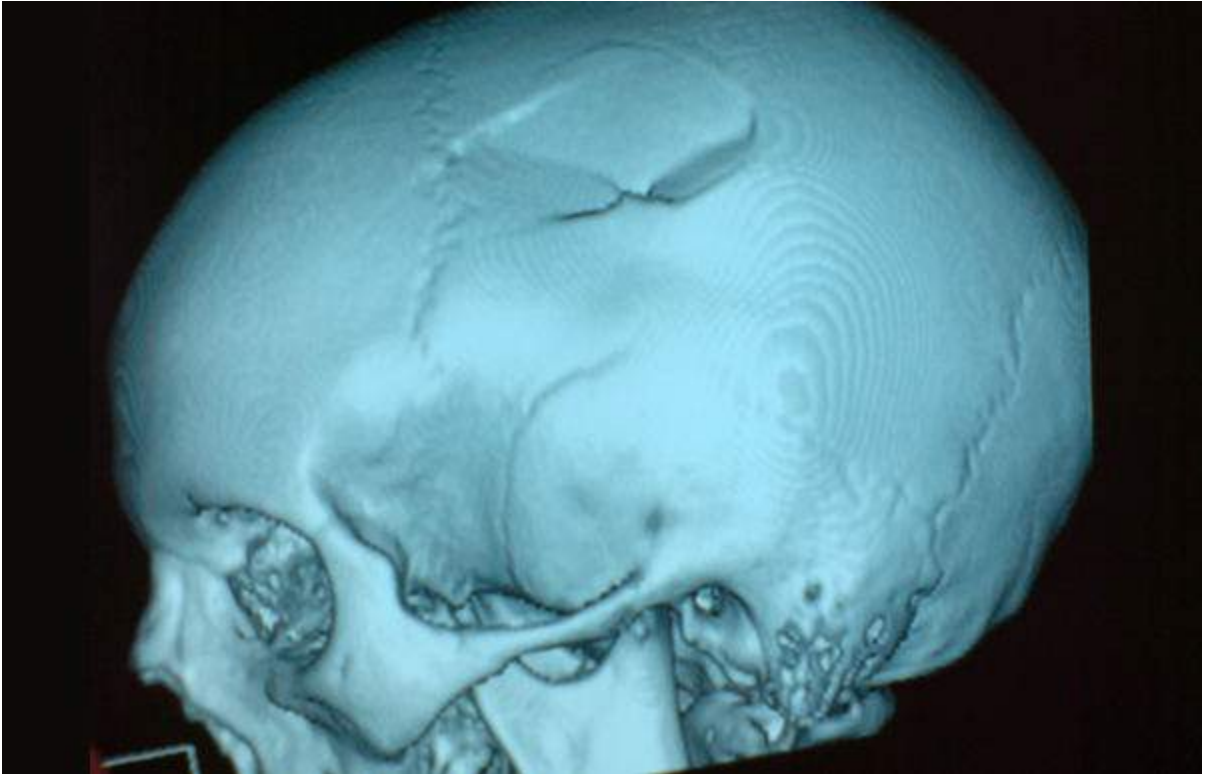
Answer:

- Intussusception
- Infection- bacterial e.g. salmonella, E.coli
-
-
-
-
-
-
-

- **Paediatric Case 6**

- **Question:**

- This 7 year old fell off a swing at the park and struck their head. They have known developmental delay and at the scene appeared confused and were difficult to assess. They are now in the ED and you have been asked to review them post CT as the nurses are concerned they may be more drowsy. How would you assess them?



- **Answer:**

- The modified Child's Glasgow Coma Scale may be helpful, as the Adult Glasgow Coma scale is difficult to use in children <4yrs old . Other helpful tools include the AVPU scoring system. The parents are also an invaluable resource especially in a child who has an underlying chronic condition as they will usually be very aware of any changes in their mental state.

Paediatric Case 7

Question:

This neonate has known Fallots Tetralogy and is in PICU. What test are they having and what is the main finding you would expect to see in this condition? List the features of Fallots Tetralogy and discuss their operative management.



Answer:

The neonate is having an ECG with the main finding likely to be right ventricular hypertrophy.

The features of Fallots are:

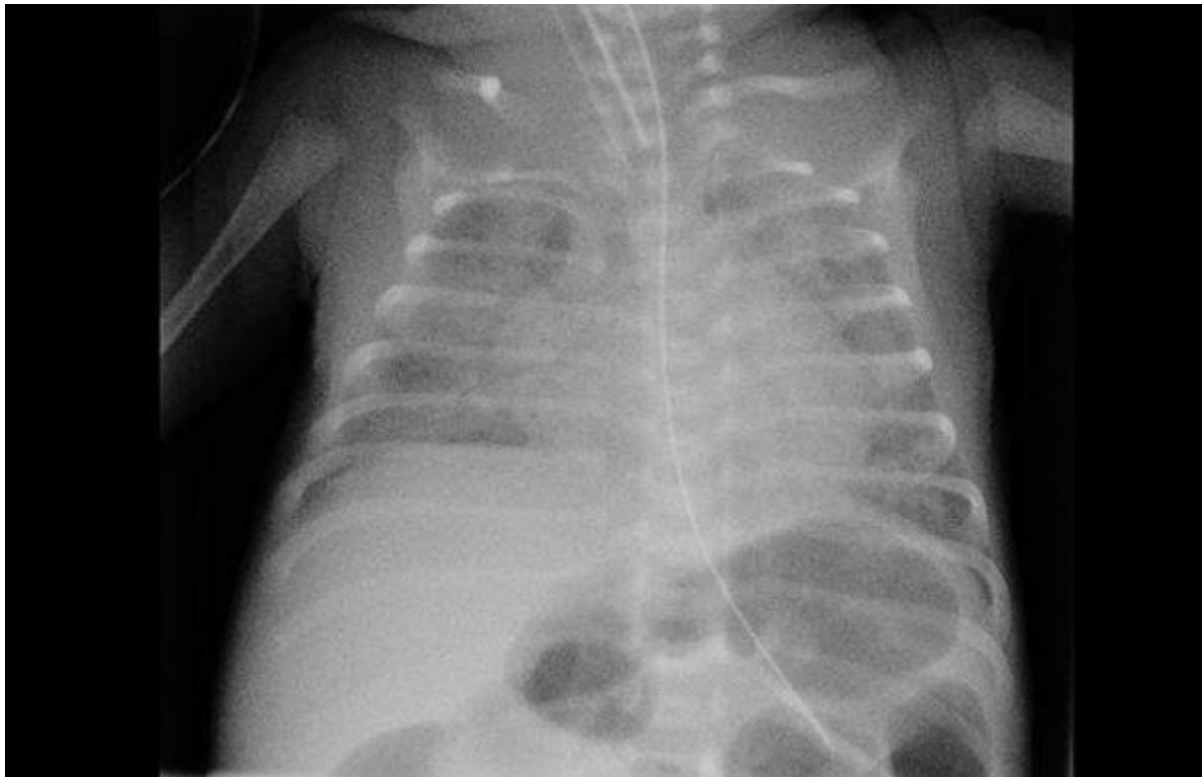
- Ventricular septal defect
- Right ventricular hypertrophy
- Right ventricular outflow tract obstruction usually at the infundibulum, valve level or at both
- Overriding aorta

Surgery is done usually before 1 year of age and carries less than 5% perioperative mortality. The surgery endeavours to relieve the right ventricular outflow tract stenosis by careful **resection** of muscle +/- use of a patch to enlarge the RVOT and to repair the VSD with a **Gore-Tex** patch or a **homograft**. Additional surgery may be done if needed depending on each child's cardiac anatomy.

Paediatric Case 8

Question:

This premature baby has had severe respiratory problems and has had multiple complications including pneumothorax and recurrent pulmonary haemorrhage. They are now being ventilated using a high frequency oscillator. Describe their CXR.



Answer:

The CXR shows the classic reticulo-granular appearance associated with respiratory distress syndrome. Other features on the CXR include an ETT and NG tube.

Paediatric Case 9

Question:

This 4 year girl had severe meningitis as a toddler and suffered major complications including spinal cord involvement resulting in quadriplegia. What devices on her CXR suggest her current respiratory status?



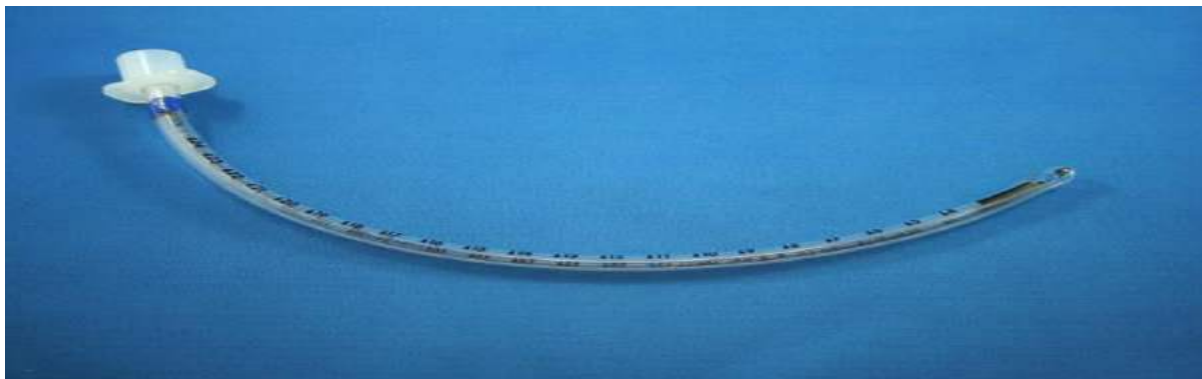
Answer:

There is a tracheostomy suggesting a need for long term respiratory support or at least the need for tracheal toilet. There are also bilateral diaphragmatic stimulators reflecting the child's inability to trigger her own breaths. Both of these devices indicate that the child is severely respiratory compromised and is likely to need on-going ventilatory support.

Paediatric Case 10

Question:

This is a standard endotracheal tube used in children. What is the main difference from an adult ETT and why are they preferred? What are the advantages of nasal intubation in critically ill children?



Answer:

This tube is uncuffed. These tubes are preferred due to the anatomy of the child's airway with the narrowest part at the cricoid ring prior to puberty rather than the vocal cords. It is known that if there is a tight seal with no leak that there is an increased risk of mucosal damage and oedema. Cuffed tubes are sometimes used especially if there is concern about the ability to ventilate non-compliant lungs. New technology 'microcuff' low pressure high volume endotracheal tubes are now available down to neonatal sizes, and have not been associated with an increased risk of subglottic stenosis or post extubation stridor compared with non cuffed tubes.

Advantages of nasal intubation:

- Can be better secured and therefore there is less risk of accidental extubation
- Mouth care is facilitated
- Better tolerated by the child

• Paediatric Case 11

• Question:

- What is the device below? Why is it useful in infants?



• Answer:

- This is a laryngoscope with a straight blade. These blades are used to directly lift the epiglottis, thereby uncovering the vocal folds. This is useful in infants in whom the epiglottis is proportionally large and usually long and stiff and therefore can cause problems by obscuring the cords. The main disadvantage is the potential for vagal stimulation causing laryngospasm or bradycardia.

Paediatric Case 12

Question:

What is the procedure below? List the three main risks associated?



Answer:

The procedure is intraosseous access. This is indicated if intravenous access cannot be established quickly.

Three risks associated are:

- Fracture
- Compartment syndrome from fluid extravasation
- Osteomyelitis

(Other risk include: Bone marrow embolism, cellulitis, pain during infusions, damage to the epiphyseal growth plate, injury to the operator)

Question:

The picture below shows an infant receiving cardiac compressions. Describe how these are done in this age group and the different method that would be employed in a 6 year old?

**Answer:**

The two-finger technique is shown; this is used if there is a single rescuer. If there are two rescuers a more effective method is the hand-encircling technique: the infant is held with the hands encircled round the chest and the thumbs are then placed on the correct position on the sternum for compressions.

In an older child, the method used involves using the heel of the hand over the lower half of the sternum. The fingers are lifted to ensure pressure is not exerted over the ribs. The sternum is depressed to one third the depth of the chest with the rescuer positioned vertically above the child and with the arm straight at the rate of 100 compressions per minute.



Paediatric Case 14

Question:

A 10yr old child presents to the ED unresponsive and pulseless. The paramedics report that his mother is a known drug addict on the methadone program. You commence advanced life support and there is no response after three cycles. What is the actual dose of the drug below you would give and what sign on examination would help confirm the diagnosis?



Answer:

The dose of adrenaline is 10mcg/kg. To calculate weight use $(\text{age} + 4) \times 2$ which in this 10yr old would make them 28kg. This would be a dose of 2.8ml of 1:10000 adrenaline.

The most likely diagnosis is a drug overdose and if the pupils were pinpoint this would support the assumption of a methadone or opiate overdose.

Paediatric Case 15

Question:

This child was brought to the ED after being involved in an MVA. They were intubated at the scene and have had one fluid bolus of 20mls/kg of normal saline using an estimated weight of 25kg. They are still tachycardic and hypotensive. What would you do next in terms of fluid resuscitation? What do you estimate the Childs total blood volume to be?



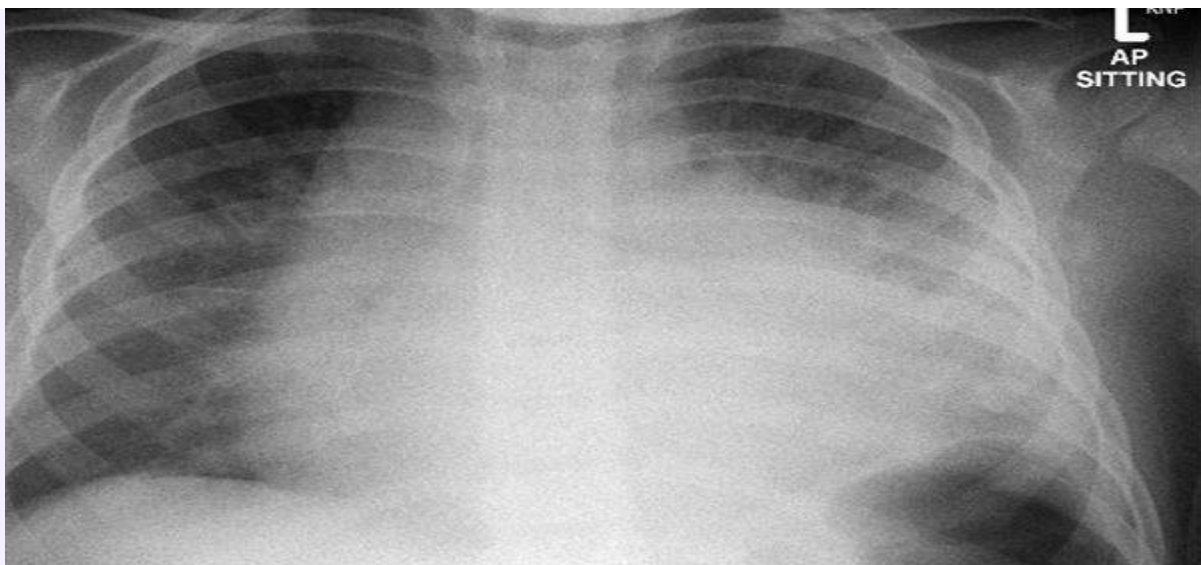
Answer:

Another fluid bolus of 20mls/kg (500mls) of normal saline and monitor response. The child's total blood volume would be approximately 2000mls. This means that after two boluses that half of the child's blood volume has been replaced and that if a third is needed packed cells should be given at a rate of 10mls/kg. This situation also suggests that there is ongoing bleeding and need for surgical involvement

Paediatric Case 16

Question:

This 2 year old boy presented with haemodynamic compromise. His CXR showed the following and he proceeded to theatre for the drainage procedure shown. Describe the CXR and suggest the most likely diagnosis on the information given.



Answer:

The CXR shows gross cardiomegaly and mediastinal enlargement. There is also marked lung plethora which is more marked on the left than the right.

The most likely diagnosis is pericardial effusion requiring pericardiotomy.

Paediatric Case 17

Question:

The equipment below is used for circulatory support in critically ill children. What is it and what are the anatomical landmarks?



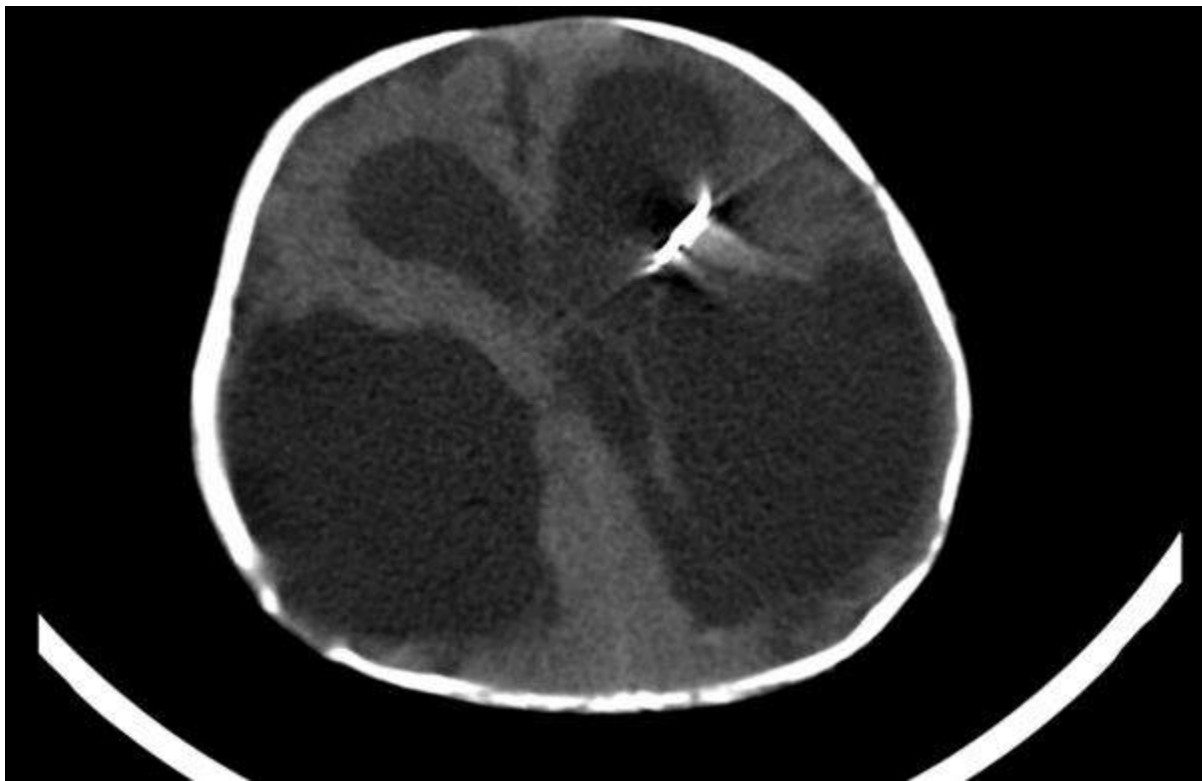
Answer:

This is an intraosseous drill kit. The anatomy on the tibia is the anterior surface medially, 2-3cm below the tibial tuberosity. The femur can also be used with the surface anatomy being as follows: anterolateral surface, 3cm above the lateral condyle.

Paediatric Case 18

Question:

This 6 month old presented with developmental delay and failure to thrive. This is a progress slice of a CT head post procedure. What are the main features?

**Answer:**

The main features are gross hydrocephalus with evidence of an EVD in situ.

Paediatric Case 19

Question:

This child has multi-organ failure and is critically unwell in the PICU. List the organ systems that you think are being supported and the devices being used.

Describe the basic principles of high frequency oscillation.



Answer:

Systems being supported are:

1. Respiratory with a high frequency oscillator.

2. Cardiovascular with multiple inotropes seen.

3. Renal with evidence of dialysis.

A pressurised circuit is produced by the passage of a continuous gas flow referred to as bias flow. This gas is oscillated by an electrically driven diaphragm at 3-15Hz. The amount of diaphragm displacement, speed of displacement, and respiratory system compliance determines the pressure variation around the mean airway pressure (delta P). This pressure is seen clinically as the amount of 'chest wiggle'. Oxygenation is determined by FiO_2 and mean airway pressure. Tidal volumes are less than the dead space and are determined by delta P, frequency, airways resistance and respiratory system compliance.

Paediatric Case 20

Question:

This child presented to ED with fevers, headache and hypotension requiring multiple fluid boluses. As you examine the child you notice this rash. How would you describe the rash and what is the likely diagnosis?



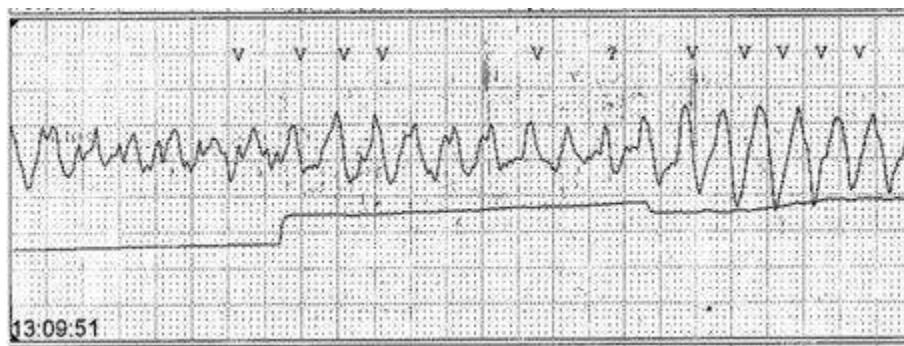
Answer:

The rash is the classic purpuric rash of meningococcal septicaemia which is the commonest cause of sepsis in infants and children. At the onset, the rash is not usually florid and a careful search should be made for purpura in all unwell children. In about 15% a blanching rash is seen instead and 7% have no rash at all.

Paediatric Case 21

Question:

This child presents to ED unresponsive and pulseless. This is their rhythm strip. What is the diagnosis and what is their management?



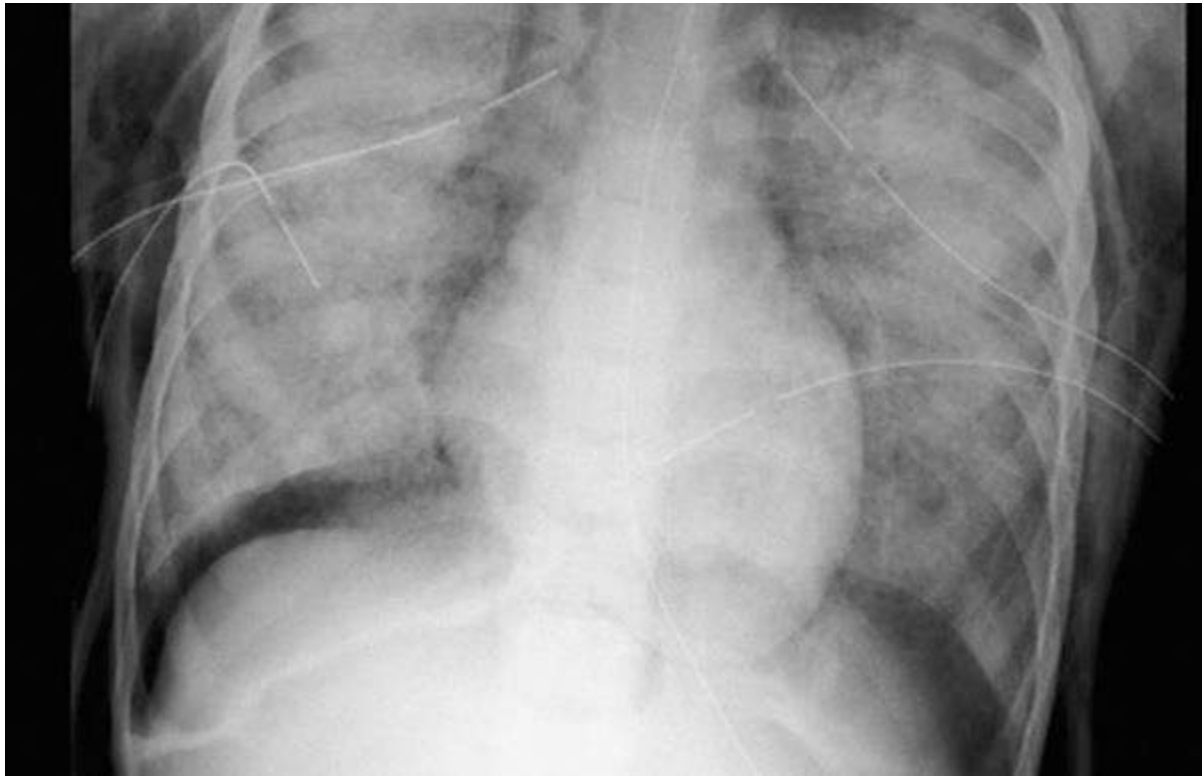
Answer:

The diagnosis is ventricular fibrillation. There is a suggestion from this rhythm strip that it is polymorphic in nature suggesting Torsades but before a firm diagnosis could be made a longer section of the rhythm strip would need to be analysed. The management is as per the ARC/ILCOR guidelines and would involve CPR and defibrillation initially with 2J/kg and then increasing to 4J/kg. If there was no response after 2 shocks, adrenaline 10mcg/kg would be given with the 3rd shock and then if the child was still in VF, Amiodarone (5mg/kg) would be given with the 4th shock. Further consideration of the polymorphic nature of the rhythm from ECG analysis may prompt use of magnesium sulphate.

Paediatric Case 22

Question:

This CXR is from a child in the PICU. Describe the salient features and list three common causes of this condition.



Answer:

The CXR shows dense airspace shadowing with very limited normal lung seen. The lungs appear hyperinflated. There is evidence of extrapleural air and subcutaneous emphysema. The child is intubated with an NG in situ and bilateral chest drains.

The appearance is consistent with acute respiratory distress syndrome (ARDS). Common causes include:

- Pneumonia
- Sepsis

-
-
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-
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-
- **Paediatric Case 23**
- **Question:**
- What is this? Explain how it is used?



BLUE				
WEIGHT	RESUSCITATION		RAPID SEQUENCE INTUBATION	
NS	Epinephrine (1:10,000)	0.21 mg (2.1 mL)	PREMEDICATIONS	
0.33 mg	Epinephrine ET (1:1,000)	2.1 mg (2.1 mL)	Atropine	0.42 mg
N/A	Atropine (0.1 mg/mL)	0.42 mg (4.2 mL)	Pan/Venecuronium	
N/A - 20kg	Atropine ET (0.4 mg/mL)	0.6 mg (1.5 mL)	(Defasciculating Agent)	0.21 mg
25 mg	Sodium Bicarbonate	21 mEq	Lidocaine	32 mg
50 mg	Lidocaine	20 mg	Fentanyl	63 mcg
ITS	Lidocaine ET	40-60 mg	INDUCTION AGENTS	
5 mg	Defibrillation		Etomidate	6.3 mg
33 mg	1st/2nd Dose (may repeat)	40J/80J	Ketamine	42 mg
5 mg	Cardioversion		Midazolam	6.3 mg
50 mg	1st/2nd Dose	20J/40J	Propofol	63 mg
TS	Adenosine		PARALYTIC AGENTS	
30 mg	1st Dose	2.1 mg	Succinylcholine (give atropine prior)	40 mg
1.5 mg	2nd Dose If Needed	4.2 mg	Pancuronium	4.2 mg
3.3 mg	Amiodarone	105 mg	Vecuronium	4.2 mg
15 mg	Calcium Chloride	420 mg	Rocuronium	21 mg
1.7 mg	Magnesium Sulfate	1050 mg	MAINTENANCE	
0.3 mg			Pancuronium/Vecuronium	2.1 mg
			Lorazepam	1 mg
18 KG	19 KG	20 KG	22 KG	

- **Answer:**
- This is a Broselow trolley. The child is measured using a Broselow tape and this then gives a weight. It is now well accepted in paediatrics that length-based weights are the most reliable for resuscitation. The system then uses a colour system to aid both equipment and medication doses for children between 3-36kg.

Paediatric Case 24

Question:

A 2 year old boy presents to ED with a 6 day history of gastroenteritis. He has a respiratory rate of 35, pulse of 145bpm, and an initial blood pressure of 90 systolic. A capillary refill time done centrally on his sternum is 4 seconds. On further examination and history from his mother he has been asking for drinks but continues to vomit and his eyes look a bit sunken. On examination you find that he has reduced skin turgor.

- Is this boy shocked and what would your management be?
- What is his fluid deficit?
- How would you calculate his maintenance fluid requirements?

Answer:

- Shock is a reflection of intravascular depletion whereas dehydration is related to total body fluid loss. Dehydration normally occurs slowly and the intravascular volume is normally maintained, however it can be associated with shock.

In this child there is evidence of shock with increased capillary refill time and tachycardia. A fluid bolus would be appropriate treatment.

Weight = (age + 4) x 2 = 12kg, so the fluid bolus would be 20 x 12 = 240mls.

- Fluid deficit is related to the % dehydration which is based on clinical examination. The most objective sign is drop in weight but it is unusual to have a pre-sickness weight available. In this child with a dry mouth and thirst associated with sunken eyes and reduced skin turgor the percentage dehydration is at least moderate or 10%.

The deficit is calculated from % dehydration x weight x 10 = total fluid deficit

In this 12kg child = 10 x 10 x 10 = 1000ml. This fluid is added to the maintenance calculated and is not given as a bolus but is generally given over 24hrs depending on the serum electrolytes.

- Maintenance fluid should be isotonic (0.9% normal saline) to avoid iatrogenic hyponatraemia. is calculated using the 4,2,1 rule or 100/50/20mls/kg total then divided into 24. In a 12kg child this equates to depending on rule used:

First 10kg = 4ml/kg/hr = 40mls + (2mls/kg/hr) = 44mls/hr

Or first 10kg = 1000mls + (50 x 2) = 1100/24 = 45mls/hr

Paediatric Case 25

Question:

A 12 week old girl who has had profuse diarrhoea for 3 days is brought into hospital. Her respiratory rate is 30, pulse 140, and capillary refill time 3 seconds. She is drowsy and floppy and the skin on her abdomen has a doughy consistency. What is your diagnosis and how would you manage her?

Na 160 mmol/L

K 4.2 mmol/L

Cl 112 mmol/L

U 12 mmol/L

Gluc 4 mmol/L

Answer:

Hypernatraemic dehydration.

These babies need careful fluid management with regular reassessment and bloods; ideally in an HDU/PICU. The sodium should be reduced slowly (Sodium Slowly, Potassium Punctually: simple rule for manipulation of electrolytes) at a rate of no greater than 10mmol/24 hrs. This child may benefit from a fluid bolus ($20\text{mls/kg} = 20 \times 5 = 100\text{mls}$ of normal saline) given there is some evidence of intravascular depletion.

Paediatric Case 26

Question:

A 5 year old girl, who is recovering from chicken pox, is brought into the emergency department having a convulsion. The paramedics have secured IV access and already given a dose of midazolam.

Her respiratory rate is 14, pulse 115 and capillary refill time normal. Glucose is normal.

What is the diagnosis?

What is your management plan?

Na 119 mmol/L

K 3.6 mmol/L

Cl 90 mmol/L

U 3.0 mmol/L

Gluc 9 mmol/L

Answer:

The diagnosis is SIADH. The management plan involves airway management if prolonged fitting and consideration of sodium replacement as other anti-seizure medications are unlikely to be effective until the sodium is >125 .

Sodium can be replaced using 3% saline and the following calculation:

Sodium deficit (in ml saline) = $Wt \times 4 \times (\text{Na aiming for (usually 125)} - \text{current Na}) / \% \text{saline to be used for replacement}$.

$$Wt = (5+4) \times 2 = 18\text{kg}$$

$$\text{Sodium deficit} = (18 \times 4) (125 - 119) / 3$$

$$= 144\text{mls of 3\% saline}$$

(Note: The biochemical pattern is also consistent with a diagnosis of cerebral salt wasting syndrome. However, it would be reasonable to suspect euvolaemia given the normal capillary refill time, acknowledging the ongoing debate regarding its usefulness, which then makes SIADH more likely)

Paediatric Case 27

Question:

An 8 year old boy has been unwell for one week with a flu-like illness, cough and vomiting. On examination he is tachypnoeic with a respiratory rate of 30 and looks pale and generally unwell.

- Describe the blood results.
- What is the diagnosis?
- Describe your initial management?

Venous gas:	Na 140mmol/L
pH 7.02	K 4.1mmol/L
pCO ₂ 23mmHg (3kPa)	Cl 111mmol/L
pO ₂ 37mmHg (5kPa)	Bicarb 5mmol/L
O ₂ sats 59%	Anion Gap 24mmol/L
BE -26.3mmol/L	Glucose 23mmol/L
HCO ₃ 5mmol/L	

Answer:

- Low pH with low pCO₂ and base deficit of 26.3mmol/L = metabolic acidosis with partial compensation. This is associated with a high glucose and raised anion gap.
- Diabetic ketoacidosis.
- Treat shock (if present) with 20ml/kg of normal saline.
Replace fluids over 24-48 hours using half normal saline, add glucose when BSL <15
Insulin infusion at starting rate of 0.1u/kg/hour.
Ensure that serum osmolarity does not drop for the first 24h, rapid reduction in serum osmolarity is associated with cerebral oedema
Look for precipitating factors including infection and consider further education/support if struggling with diabetic management.

• Paediatric Case 28

• Question:

- A 4yr old girl presented with diarrhoea and being generally unwell for the past week. Her mother says she has been increasing irritable and seems to be unsteady on her feet.
- What is the diagnosis?

Hb 43g/L	Na 136mmol/L
WCC 12.5x10 ⁹ /L	K 3.8mmol/L
Plat 98 x10 ⁹ /L	Cl 100mmol/L
Retics 295 x10 ⁹ /L	Bicarb 19mmol/L
Film: Polychromasia, spherocytes, helmet cells and fragmented cells	Urea 42.3mmol/L
PT 13.6secs	Creat 274µmol/L
INR 1.0	
APTT 23.2secs	
Fib 3.8g/L	

• Answer:

- Haemolytic Uraemic Syndrome
- This is a multi-system disease of the microcirculation. It often follows E.coli enteric infection and can lead to renal failure. Treatment is supportive, but may include plasmapheresis and dialysis.

- **Paediatric Case 29**

- **Question:**

- This 6 week old baby boy presents with a history of poor feeding since birth and for the last 2 days projectile vomiting.
- What is the diagnosis?

Na 136mmol/L	Venous gas: pH 7.39
K 3.2mmol/L	pCO ₂ 67mmHg (8.9kPa)
Cl 86mmol/L	pO ₂ 30mmHg (4kPa)
Bicarb 39mmol/L	BE +12.5mmol/L
Anion gap 11mmol/L	HCO ₃ 39mmol/L
Glucose 5.6mmol/L	
Lactate 2.6mmol/L	

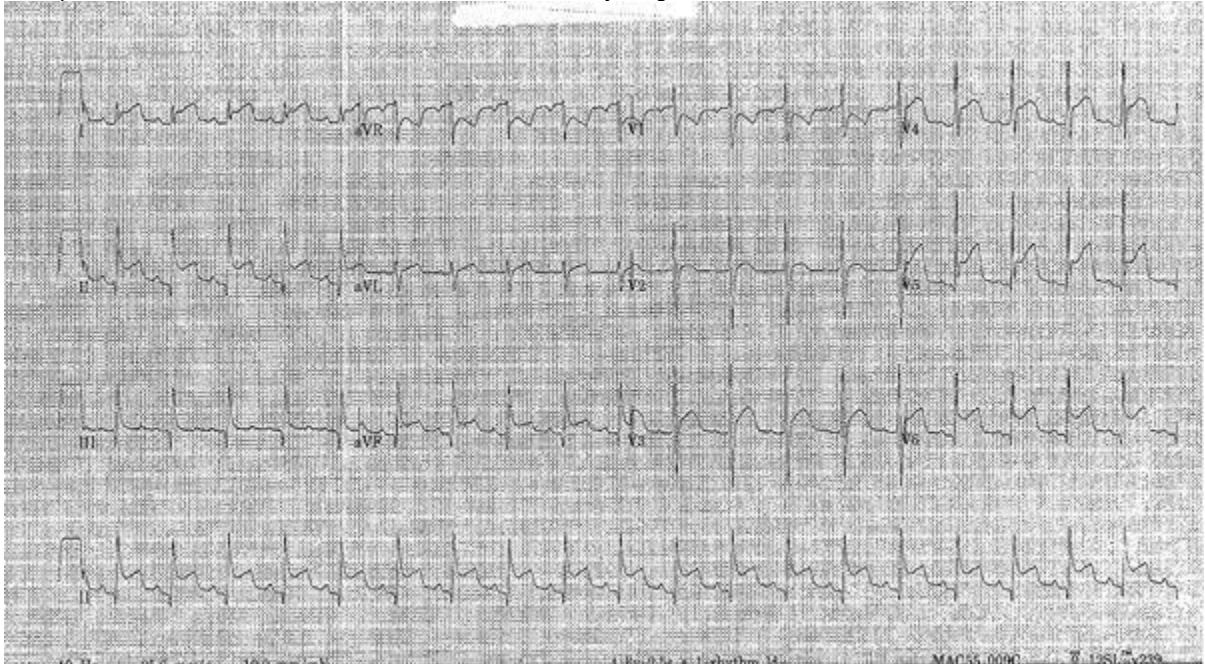
- **Answer:**

- Pyloric Stenosis.
- Classically the gastric outlet obstruction produces hypochloraemic metabolic alkalosis. Other responses include a secondary hyperaldosteronism secondary to hypovolaemia and retention of CO₂ as compensation to the metabolic alkalosis.

- **Paediatric Case 30**

- **Question:**

- This 10yr old boy presented with fevers and feeling generally unwell. He complained of chest pain on taking a deep breath. Describe his ECG and state the most likely diagnosis.



- **Answer:**

- The ECG shows a sinus tachycardia and widespread ST elevation with a saddle shape appearance consistent with pericarditis.

EXAM module

Lab data – Case 31

Question:

A 79 year old lady is in your ICU being treated for severe necrotising pancreatitis. A blood culture that was taken following a new fever is returned. What therapeutic strategy would you choose?

Blood culture

Site: Blood

Culture: 10^3 cfu Enterococcus faecium (Van-A) isolated

Site: CVC

Culture: 10^4 cfu Enterococcus faecium (Van-A) isolated

Answer:

Strategy:

- Replace all vascular catheters, ideally with a 72 hour gap if feasible, and consider using an antibiotic impregnated catheter
- Send repeat blood cultures from peripheral sites, the old catheters prior to removal and the new catheters once sited. Also send the old catheter tips for culture.
- Start synercid or tygecycline, given the presence of a septicaemia.
- Move the patient to an isolation room and employ full barrier nursing procedures, especially hand washing.

Lab data – Case 30

Question:

A 32 year old gentleman is admitted to your ICU for management of his septic shock following a right sided percutaneous nephrostomy tube insertion for obstructive ureterolithiasis which has resulted in right sided pyelonephritis. He has been commenced on empiric ceftriaxone and is on $0.7\mu\text{cg/kg/min}$ of noradrenalin. The following day a microbiology report is phoned through to the department and handed to you. What would you do next?

Urine microscopy

RBCs $>100 \times 10^9/\text{ml}$

WBC $> 100 \times 10^9/\text{ml}$

Epithelial $< 10 \times 10^9/\text{ml}$

Organisms seen

Culture: Pure growth E.coli

This organism has tested positive for ESBL

Answer:

Intervention: Change the cephalosporin antibiotic to a carbapenem; e.g. meropenem, imipenem.

Lab data – Case 7

Question:

A 45 year old gentleman is brought to the emergency with increasing dyspnoea. His family have noted that his behaviour recently has been unusual and admit that he is prone to episodic alcohol binges. On examination, he is tachypnoeic and has a distended abdomen.

What is the likely diagnosis and how would you grade it?

Urea 4.1mmol/L	FiO2 28%
Creatinine 72µmol/L	pH 7.46
Na 129mmol/L	PCO2 34mmHg / 4.53 kPa
K 2.9mmol/L	PO2 88mmHg / 11.73kPa
Cl 92mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 6.4mmol/L	Hb 93g/dL
	MCV 107fl (normal 78-101 fl)
Ca 1.85mmol/L	MCH 27pg (normal 25-35 pg/cell)
Mg 0.68mmol/L	WBC 8.1x10 ⁹ /L
PO4 0.75mmol/L	PLT 105x10 ⁹ /L
Albumin 26g/L	

	aPTT 39s
Bilirubin 6 μ mol/L	PT 22s
AST 33U/L	INR1.5
ALT 42U/L	
GGT 57U/L	
ALP 94U/L	
Serum Osm 270mOsm/kg	
Urine Osm 224mOsm/kg	
Urine Na 7mmol/L	

How would you interpret the results of the abdominal paracentesis and how do they affect your choice of therapy?

<u>Ascitic fluid</u>
Glucose 2.3 mmol/L
Albumin 54 g/L
pH 7.32
WBC 577 x10 ⁹ /ml
Polymorphs 444 x10 ⁹ /ml
RBC 89 x10 ⁹ /ml
Gram stain: Polymorphs ++
Culture: Pure growth of Enterobacter species

Answer:

Diagnosis: Hepatic encephalopathy due to spontaneous bacterial peritonitis on a background of alcoholic cirrhosis, Childs-Pugh Grade B. The identification of an enterobacter species, an ESCAPM organism, narrows the available choice of antibiotics to gentamicin or a carbapenem.

Lab data – Case 13

Question:

You are called to see a 29 year old woman, 33 weeks pregnant with a respiratory rate of 55/min. Her pregnancy has been complicated by persistent gestational nausea. She is otherwise healthy. The following pathology is available.

a) What is the likely diagnosis?

Day 1	Day 2
Urea <0.7 mmol/L	Urea <0.7 mmol/L
Creatinine 49 µmol/L	Creatinine 51 µmol/L
Na 135 mmol/L	Na 136 mmol/L
K 3.6 mmol/L	K 4.0 mmol/L
Cl 109 mmol/L	Cl 114 mmol/L
TCO2 9 mmol/L	TCO2 7 mmol/L
Urate 0.6 mmol/L	Osm 290 mOsm/kg
Hb 12.3 g/dL	Ca 2.35 mmol/L
WCC 15.9 x10 ⁹ /L	Mg 0.79 mmol/L
PLT 256 x10 ⁹ /L	PO4 0.98 mmol/L
	Albumin 32 g/L
	Prot 73 g/L

	Bilirubin 14 µmol/L
	ALT 29 U/L
	AST 96 U/L
	GGT 34 U/L
	ALP 217 U/L
	Glucose 4.3 mmol/L
	pH 7.19
	PaCO ₂ 17 mmHg / 2.27 kPa
	PaO ₂ 124 mmHg / 16.53 kPa
	HCO ₃ 7 mmol
	SBE -19 mmol/L
	Lactate 0.69 mmol/L
	Hb 12.3 g/dL
	WCC 17.3 x10 ⁹ /L
	Plt 339 x10 ⁹ /L

b) She was subsequently treated appropriately. The following day, her morning bloods return What complication has occurred?.

Na 135 mmol/L	Ca 2.00 mmol/L
---------------	----------------

K 3.5 mmol/L	Mg 0.85 mmol/L
Cl 110 mmol/L	PO4 0.36 mmol/L
TCO2 17 mmol/L	Albumin 21 g/L

Answer:

a) Starvation ketosis in pregnancy.

b) Refeeding syndrome.

Lab data – Case 21

Question:

A 48 year old lady is brought to the emergency department confused and febrile, with a heart rate of 140bpm and a blood pressure of 220/97mmHg. She appears mildly cachectic. Her blood tests are presented below.

Na 144 mmol/L	Hb 11.6 g/dL
K 4.4 mmol/L	WBC $15.7 \times 10^9/L$
Cl 106 mmol/L	Neut $14.7 \times 10^9/L$
HCO ₃ 23 mmol/L	Lymph $0.5 \times 10^9/L$
Urea 18.3 mmol/L	MCV 84fl (normal 78-101 fl)
Creatinine 253 µmol/L	MCH 30 (normal 25-35 pg/cell)
	MCHC 34.6 (normal 31 – 36 Hb/cell)
Glucose 11.5 mmol/L	RDW 13.4
CK 562 U/L	PLT $86 \times 10^9/L$
Ca 2.11 mmol/L	

PO4 1.38 mmol/L	
Mg 1.10 mmol/L	
Free T4 47.8 pmol/L (10.5 – 21.2pmol/L)	
TSH 0.050 mIU/L (0.35 – 0.36mIU/L)	
Free T3 6.6 pmol/L (2.5 – 7.3pmol/L)	

What specific therapy would you suggest?

Answer:

Therapy, in order of administration:

- Decrease the systemic sensitivity of catecholamine receptors and the peripheral conversion of T4 to T3 using non-selective β -blocker: Propranolol 0.5 – 1mg IV q5min until HR less than 100bpm to maximum 10mg, then enteral propranolol 60 – 120mg q4hr until the crisis abates. Cardioselective β -blockers can be used, but are less effective. Guanethedine or reserpine are used in patients with reactive airways disease or other contraindications to β -blockers.
- Reduce thyroid hormone synthesis: Enteral propylthiouracil 1000mg loading dose, then 200 – 400 mg q4hr. Carbimazole has also been used.
- Reduce the release of preformed thyroid hormone: Lugol's iodine 8 - 10 drops q6hr enterally. Alternatively, iodinated contrast agent can be used if Lugol's iodine is not available.
- Steroids: Hydrocortisone 300 mg loading followed by 100 mg tds, as there is often a relative hypoadrenalism. It also alters the peripheral conversion of existing thyroid hormones. .
- Treat the precipitant – usually sepsis.
- Supportive therapy – fluid balance, nutritional support, avoid salicylates and frusemide which can release bound thyroid hormone, active cooling of hyperpyrexia, thiamine and sedation if agitated.

Lab data – Case 14

Question:

A 19 year old gentleman presents with abdominal pain and vomiting. He looks dehydrated and pale. He has no known medical history. His observations are as follows: HR 118bpm sinus, BP 104/62mmHg, RR 32bpm, SpO2 100%, Temp 37.8°C, Urine output 100 – 140ml/hr. How will you manage him initially?

Urea 17.8mmol/L	pH 7.13
Creatinine 103 μ mol/L	PaCO2 15 mmHg / 1.99 kPa

Na 130 mmol/L	PaO ₂ 124 mmHg / 16.53 kPa
K 3.0 mmol/L	HCO ₃ 7 mmol
Cl 87 mmol/L	SBE -21 mmol/L
TCO ₂ 11 mmol/l	Lactate 4.7 mmol/L
Osm 305mOsm/kg	Hb 13.1 g/dL
Ca 2.43 mmol/L	WCC 16.3 x10 ⁹ /L
Mg 0.54 mmol/L	Plt 532 x10 ⁹ /L
PO ₄ 1.06 mmol/L	
Albumin 43 g/L	
Bilirubin 11 µmol/L	
ALT 27 U/L	
AST 35 U/L	
GGT 28 U/L	
ALP 100U/L	
Glucose 24 mmol/L	
Lipase 68U/L	

Answer:

Management:

- IV rehydration with crystalloid, often requiring a 4 – 6 litre replacement over the next 24 – 48 hours, depending upon the rapidity of the onset of this illness.
- IV insulin infusion at 1 – 3 u/hr, aiming for a fall in blood glucose of 1mmol/L/hr, to prevent any cerebral osmotic shifts
- K⁺ replacement will be required with the insulin infusion, given the total body K⁺ depletion evident
- Search for and treat the precipitant; commonly sepsis, trauma or drugs in a young person.

Lab data – Case 28

Question:

A 65-year-old man underwent a Whipple's procedure for resection of a pancreatic adenocarcinoma. An anastomotic leak and pancreatic fistula complicated this. Total parenteral nutrition was provided. After a month of TPN trace elements were ordered and the results shown:

Plasma/serum chromium 5 nmol/L (1-26 nmol/L)

Plasma/serum selenium 0.9 µmol/L (0.9-1.4 µmol/L)

Plasma/serum zinc 2.6 µmol/L (10-19 µmol/L)

Plasma/serum copper 14.8 µmol/L (12-22 µmol/L)

Blood manganese 90 nmol/L (60-350 nmol/L)

Blood selenium 1.1 µmol/L (1.2-2.1 µmol/L)

Comment on the findings.

Answer:

The results suggest a deficiency of zinc and to a lesser degree selenium.

Both trace elements are known to commonly fall in critically ill patients, including surgical patients requiring TPN. Both are important antioxidants involved in host defense against free radicals. Zinc is also involved in wound healing and glycaemic control. The risks, benefits and most appropriate regimen for replacing trace elements in the critically ill patient remains unclear although this is an area of current active research.

Lab data – Case 10

Question:

A 25 year old gentleman is admitted to your ICU heavily sedated, intubated and ventilated following a fall from construction scaffolding. He sustained rib fractures and significant head injury. He has just returned from the

operating theatre, where a decompressive craniectomy was performed. What is your explanation for his initial blood picture?

Urea 7.3mmol/L	Serum Osm 334mOsm/kg
Creatinine 87µmol/L	Urine Osm 417mOsm/kg
Na 151mmol/L	Urine Na 32mmol/L
K 2.6mmol/L	
Cl 116mmol/L	Ca 2.25mmol/L
TCO2 26mmol/L	Mg 0.87mmol/L
	PO4 0.96mmol/L
BSL 8.1mmol/L	Albumin 32g/L

Answer:

Diagnosis: Recent mannitol therapy

Lab data – Case 1

Question:

A 59 year old lady on the ward has recently been treated for painful active rheumatoid arthritis. While awaiting completion of her discharge planning, a MET call is put out for a witnessed collapse that occurred when she got up to use the bathroom. The first intravenous volume bolus has not improved her blood pressure. What therapy would you consider next?

Urea 11.2mmol/L	Ca 2.37mmol/L
Creatinine 91µmol/L	Mg 0.87mmol/L
Na 127mmol/L	PO4 1.01mmol/L
K 5.9mmol/L	
Cl 96mmol/L	Albumin 36g/L
TCO2 21mmol/L	

BSL 4.1mmol/L	
Serum Osm 273mOsm/L	
Urine Osm 315mOsm/L	
Urine Na 47mmol/L	
Urine Cl 21mmol/L	

Answer:

Therapy: 100mg Hydrocortisone IV or 4mg Dexamethasone IV and then reinstate a regular oral dose of prednisone. Using dexamethasone will not preclude performing a short synacthen test.

Lab data – Case 20

Question:

A 72 year old gentleman has been intubated in the emergency department for increasing work of breathing and a decline in his level of consciousness during the management of his suspected community acquired pneumonia. The nurse looking after him shows you his first blood gas following his transfer to the ICU. What measures would you take?

FiO2 0.5	Hb 9.1g/dL
pH 7.49	Na 137 mmol/L
PaCO2 26 mmHg	K 3.7mmol/L
PaO2 101 mmHg	iCa 1.13 mmol/L
HCO ₃ 20 mmol/L	iCa (pH 7.40) 1.18mmol/L
SBE -2.8	Glucose 6.3 mmol/L
SaO2 98%	Lactate 1.1 mmol/L

Answer:

Measures to take: Check the ventilator minute ventilation, ventilator frequency and tidal volume. Usually a decrease of the frequency is all that is required. The tidal volume may need to be reduced if inappropriately high. Check that the patient is not in pain and has an appropriate level of sedation to assist tolerance of invasive ventilation. Exclude alternative pathologies, such as meningitis, encephalitis, cerebral oedema or drug toxicities (e.g. salicylate, theophylline).

Lab data – Case 32

Question:

A 74 year old gentleman is admitted to the ICU for management of septic shock due to a community acquired pneumonia. He is difficult to ventilate and a CXR shows a large left sided pleural effusion. This is therapeutically tapped and the cloudy fluid sent for analysis. What is your interpretation of the results?

<u>Pleural fluid</u>	<u>Blood</u>
Glucose 0.1 mmol/L	Urea 12.6 mmol/L
Protein 54 g/L	Creatinine 173 µmol/L
LDH 4522 U/L	Na 135 mmol/L
pH 7.12	K 5.0 mmol/L
	Cl 102 mmol/L
WBC > 10 x10 ⁹ /ml	HCO ₃ 24 mmol/L
RBC > 10 x10 ⁹ /ml	
	Bili 10µmol/L
Gram stain: Polymorphs + +	ALT 23 U/L
	AST 26 U/L
	ALP 34 U/L

	GGT 45 U/L
	LDH 202 U/L
	Protein 64 g/L
	Albumin 20 g/L
	Glucose 9.2 mmol/L

Answer:

Diagnosis: Empyema

Lab data – Case 12

Question:

A 37 year old lady is admitted to the maternity ward at 34 weeks gestation (G2P1) with upper abdominal discomfort and a sensation that her shoes and rings are too tight. She has not attended any ante-natal care. On examination she has a fundal height of 35cm and six beats of clonus. Her urine appears dark. Her observations are as follows, HR 102bpm sinus, BP 133/87mmHg, RR 18bpm, SpO2 100% on nasal prongs at 4L/min, Temp 37.1°C. What management conflicts do you face for this patient?

Urea 5.9mmol/L	FiO2 28%
Creatinine 62µmol/L	pH 7.43
Na 132mmol/L	PCO2 32mmHg / 4.27 kPa
K 3.4mmol/L	PO2 121mmHg / 16.13 kPa
Cl 95mmol/L	HCO ₃ 22mmol/L
TCO2 21mmol/L	SBE -2
BSL 5.1mmol/L	Hb 94g/dL

	MCV 108fl (normal = 78-101 fl)
Ca 2.14mmol/L	MCH 37pg (normal = 25-35 pg/cell)
Mg 0.72mmol/L	WBC 12.3x10 ⁹ /L
PO4 0.92mmol/L	PLT 125x10 ⁹ /L
Albumin 33g/L	
	aPTT 34s
Bilirubin 56µmol/L	PT 21s
AST 137U/L	INR1.4
ALT 144U/L	
GGT 108U/L	
ALP 139U/L	
Serum Osm 273mOsm/kg	
Urine Osm 182mOsm/kg	
Urine Na 9mmol/L	
Urine protein + + +	

Answer:

Conflicts:

1. The patient is demonstrating features of evolving pre-eclampsia and HELLP syndrome. However, at 34 weeks gestation, foetal lung maturity is underdeveloped and a dose of dexamethasone 24 hours prior to delivery is desirable. Providing this period without excessive risk to the mother's health is a delicate timing issue.

2. Operative intervention in the setting of an uncontrolled coagulopathy presents an increased bleeding risk. The blood products used to correct the coagulopathy have a higher than usual risk of precipitating pulmonary oedema in this population of patients.

3. Once in the ICU, there is often a conflict of interest between supporting renal perfusion with fluids and precipitating pulmonary oedema. Both are transient, but most centres give preference to preventing pulmonary oedema and accepting a period of oliguria and deranged renal biochemistry.

Lab data – Case 5

Question:

A 34 year old lady, who was admitted with a fever, altered behaviour and a rapid decrease in level of consciousness necessitating invasive airway support, has been noted to have a urine output consistently greater than 150mls/hr. A lumbar puncture is performed and the result, along with her biochemistry is displayed below. What is her diagnosis?

Urea 13.3mmol/L	<u>Lumbar puncture</u>
Creatinine 125µmol/L	Microscopy
Na 152mmol/L	RBC 3×10^9 /ml
K 3.8mmol/L	Polymorph 32×10^9 /ml
Cl 118mmol/L	Mono 10×10^9 /ml
TCO2 23mmol/L	No organisms seen
	Glucose 4.4mmol/L (2.5 – 5.5mmol/L)
Serum Osm 319mOsm/kg	Protein 0.78g/L (0.15 – 0.45g/L)
Urine Osm 236mOsm/kg	
Urine Na 74mmol/L	Cryptococcal Atg negative
Ca 2.41mmol/L	
Mg 0.96mmol/L	
PO4 1.10mmol/L	
Albumin 44g/L	
BSL 6.2mmol/L	

Uric acid 0.61 mmol/L	
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Answer:

Diagnosis: Cranial diabetes insipidus secondary to viral encephalitis

Lab data – Case 35

Question:

A 45 year old renal transplant patient is admitted to hospital with fevers, a dry cough and a single episode of haemoptysis. An ICU consult is sought when, on the ward, his oxygen saturation deteriorates and his work of breathing increase, despite increasing his FiO₂ to 15L/min via non-rebreather mask. On examination, he is in moderate respiratory distress and hypoxic with a tachycardia and normal blood pressure. His CXR shows bilateral patchy infiltrates. He is intubated and a bronchoscopic BAL is performed. List the possible responsible organisms and the antimicrobial agent would you commence.

Answer:

Bacterial	Antimicrobial agent
<ul style="list-style-type: none">• Typical community acquired organisms (strep, haemophilus, moraxella)• Atypical non-zoonotic community acquired organisms (legionella, mycoplasma, chlamydia pneumonia)• Atypical zoonotic community acquired organisms (chlamydia psittaci, Q fever, Francisella tularensis)• High risk community acquired pneumonia (staphylococcus, enteric gram negative organisms)• Nosocomial organisms• TB	<ul style="list-style-type: none">• Benzylpenicillin, ampicillin or ceftriaxone + macrolide (e.g. azithromycin)• Ampicillin + macrolide (e.g. azithromycin)• Doxycycline, moxifloxacin or a macrolide (e.g. azithromycin)• Flucloxacillin• Ceftriaxone or moxifloxacin• Timentin + gentamicin ± vancomycin• Rifampicin + isoniazid (pyridoxine) + pyrazinimide + ethambutol• Ganciclovir• Aciclovir or Valaciclovir• Aciclovir or Valaciclovir• Co-trimoxazole (Bactrim)• Voriconazole• Generally fluconazole sensitive, unless C. glabrata or C. krusi, in which cases use amphotericin B or voriconazole
Viral	
<ul style="list-style-type: none">• CMV• HSV• Chicken pox	
Fungal	
<ul style="list-style-type: none">• Pneumocystis jiroveci (formerly PCP)	

- Invasive aspergillosis
- Invasive candidiasis

Lab data – Case 27

Question:

This 70 year old female presented with dizziness and had a history of recent syncopal episodes. On examination she had a loud ejection systolic murmur noted which radiated to her carotid arteries. An echocardiogram demonstrated severe aortic stenosis with features suggesting a calcification bicuspid valve. She was admitted for surgery and the following pre-operative blood results were noted:

WBC $5.0 \times 10^9/L$ (3.5-10)	HCT 0.16 (normal 0.35-0.40)
RBC $1.94 \times 10^9/L$ (3.8-5.1)	MCV 70 fl (normal 78-101 fl)
HGB 48 g/L (120-150)	MCH 22 pg/cell (normal 25-35 pg/cell)

a) Interpret the results. What is the most common cause of this picture? What test will you order to confirm your suspicion?

b) The patients Iron studies were performed.

Iron $3 \mu\text{mol/L}$ (low)

Total Iron Binding Capacity $92 \mu\text{mol/L}$ (high)

Ferritin $6 \mu\text{g/L}$ (low)

Do these results confirm your suspected diagnosis? What is a single unifying diagnosis that would tie together this picture and severe aortic stenosis?

Answer:

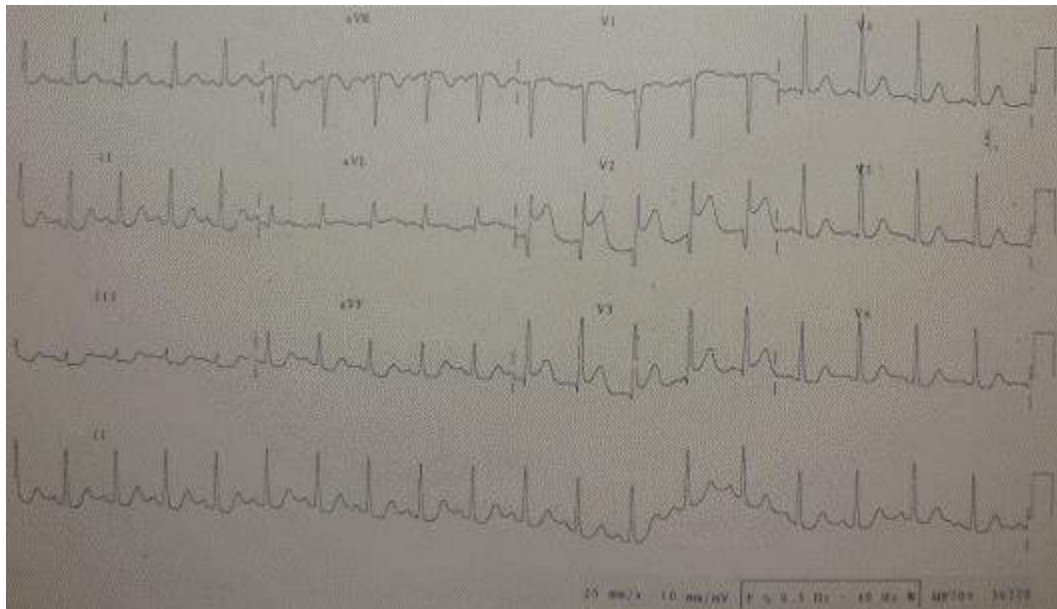
a) There is a marked microcircuit, hypochromic anaemia. The most likely cause is iron deficiency anaemia. Iron studies will be helpful.

b) Yes. The results are consistent with Iron deficiency anaemia. There are a number of potential causes of this that need investigating, but angiodysplasia is a known association with severe aortic stenosis where it is termed Heyde's Syndrome. It is thought that von Willebrand factor is proteolysed due to high shear stress from turbulent flow across the diseased aortic valve, increasing the risk of bleeding from intestinal telangiectasias that are increasingly common with advancing age.

ECG – Case 11

Question:

Outline your management of a patient who develops the following ECG.



Answer:

Diagnosis = Anteroseptal AMI with reciprocal changes in the inferior leads

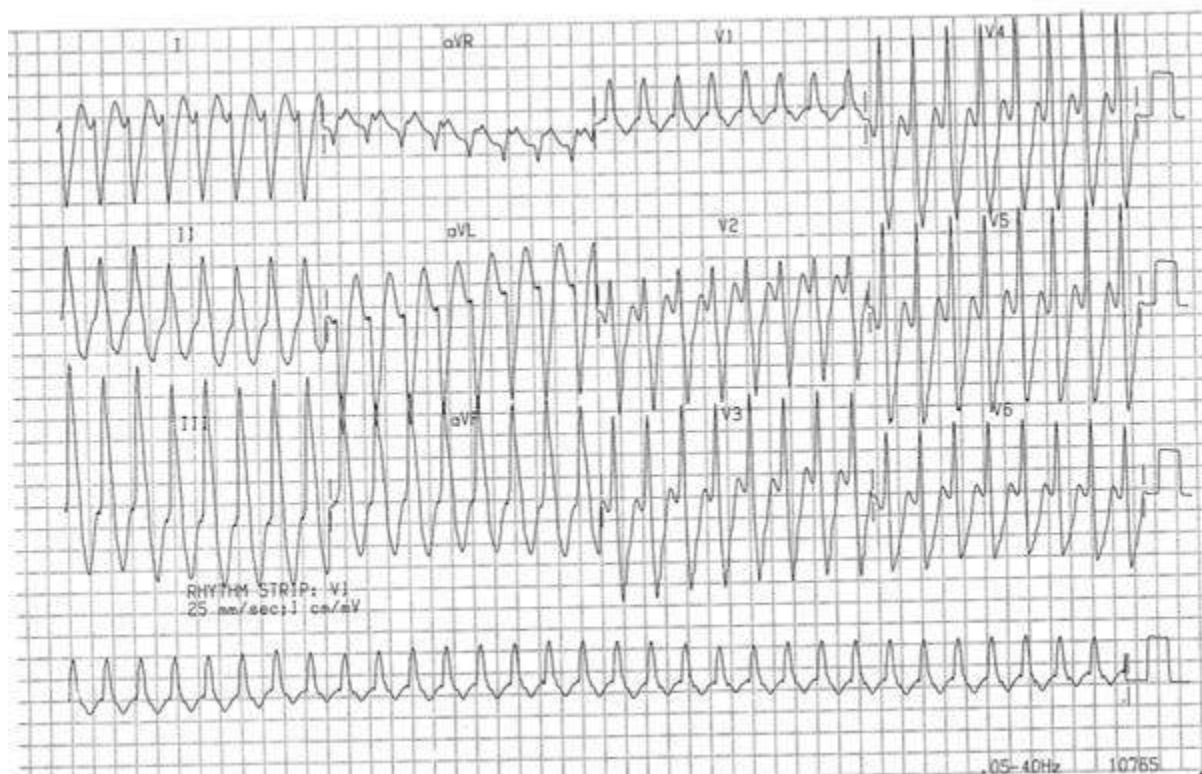
Management:

1. Resuscitation as required
 - support oxygenation and ventilation
 - support blood pressure with IV fluid and, if necessary, an inotrope such as adrenalin
2. Urgent reperfusion with PCI within 60 minutes if the patient presents within 60 minutes of symptom onset, otherwise within 90 minutes if the patient presents within 12 hours of symptom onset. If PCI is not available, or cannot be performed within the recommended window, then use IV thrombolysis, aiming for a door-to-needle time of 30 minutes.
3. Antiplatelet therapy – aspirin, clopidogrel (if not having a PCI)
4. Analgesia – sublingual nitrate, IV morphine
5. IV heparin for a minimum of 48 hours, aiming for an aPTT of 60 - 90s
6. β -blockade aiming for a HR of 60 – 90bpm
7. Screen for remediable risk factors
8. Monitor for complications of an AMI, especially heart failure in this context.
9. Start a myocardial remodeller, e.g. ACE inhibitor or carvedilol, once that patient is stable.

ECG – Case 12

Question:

What ECG features would you use to determine the source of this tachyarrhythmia?



Answer:

Diagnosis = Broad complex tachyarrhythmia, likely to be an SVT with aberrant conduction.

Features used to differentiate between a VT and an SVT with aberrant conduction

VT

- Concordance – i.e. all of the QRS complexes point in the same direction, either positive or negative
- Fusion beats – an atrial impulse is conducted successfully through to the ventricle and merges with a VT wave, producing a complex with a bizarre broad morphology
- Capture beats – an atrial impulse is conducted successfully through to the ventricle, resulting in the appearance of a normal P-QRS complex amidst the VT activity
- AV dissociation – P waves may be visible intermittently, but are not conducted effectively
- Leftward axis
- QRS > 140ms (3½ small boxes)

SVT with aberrance

1. Essentially the opposite of VT, although the QRS duration may be similarly prolonged, particularly if there is a pre-existing or rate-related BBB
2. If the broad complex tachyarrhythmia is irregular, then the decision is between VF (no output) and AF with aberrancy (may be hypotensive)

Description

A regular, broad complex tachyarrhythmia at approximately 160bpm

Right axis, possibly due to a rate-related BBB, consistent with an SVT with aberrancy

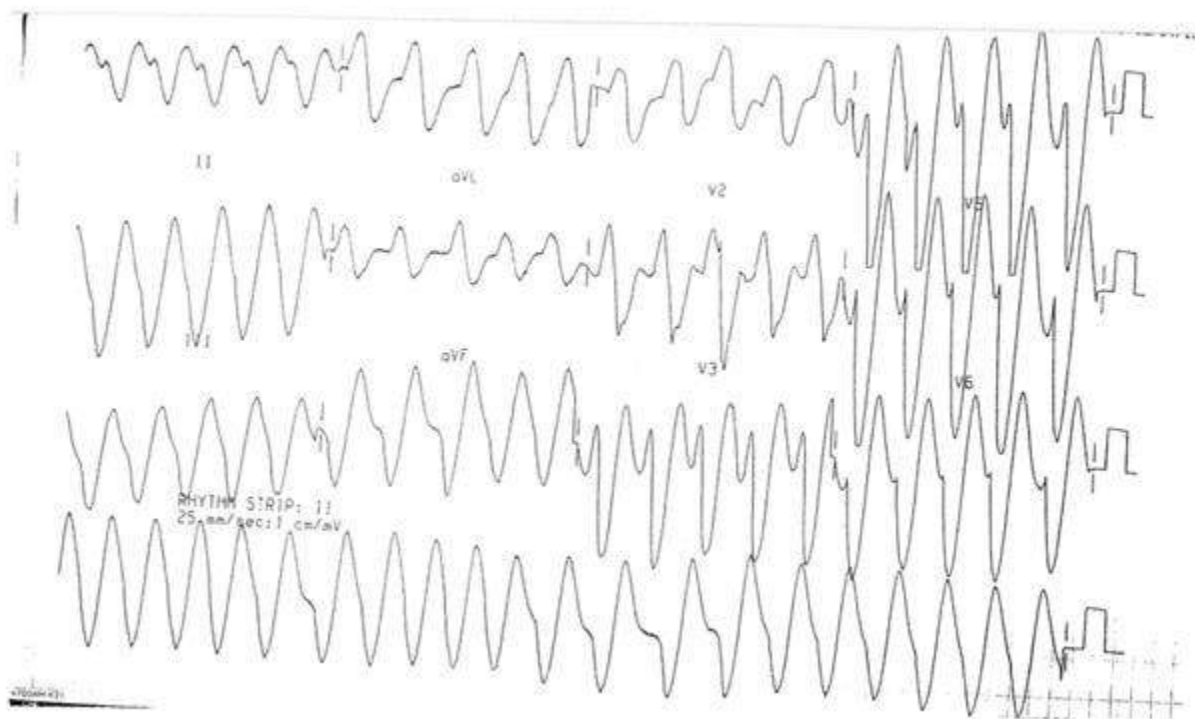
No visible P-waves, fusion beats or capture beats

Absence of a visible P-wave suggests an AVNRT

ECG – Case 16

Question:

A patient with a history of hypertension, depression and gout presents to the emergency department. Outline your management of the condition responsible for the following ECG.

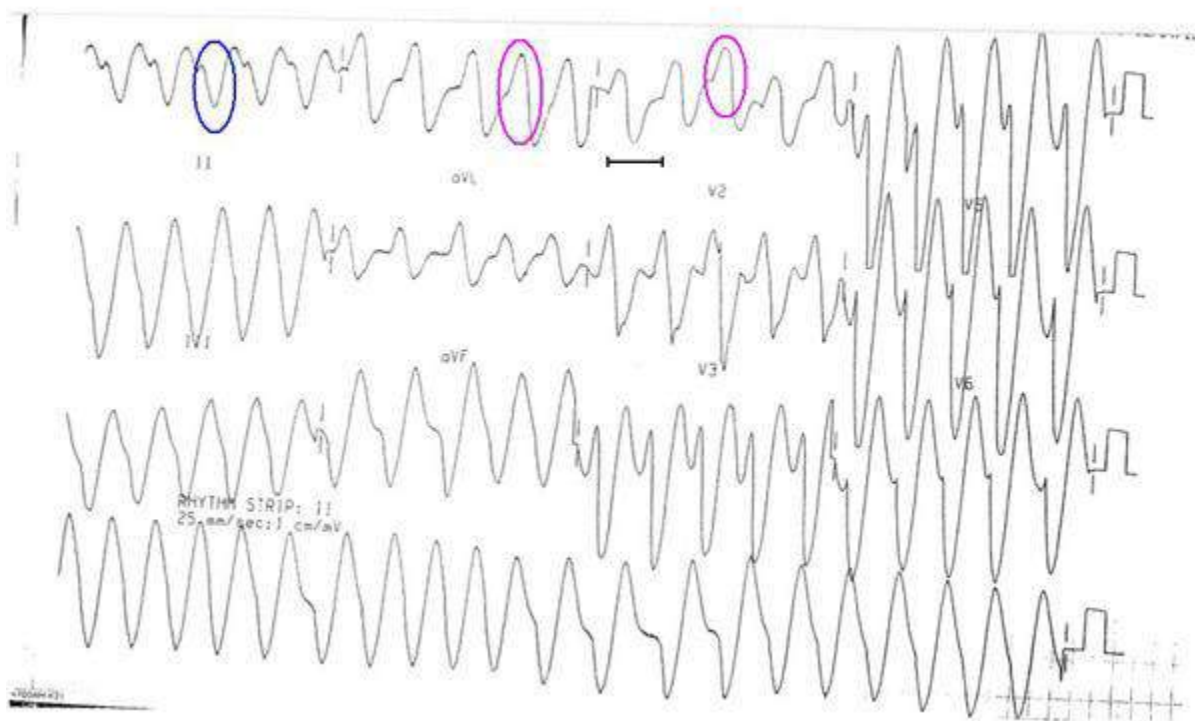


Answer:

Diagnosis = Tricyclic antidepressant toxicity

Management

1. Support oxygenation and ventilation
2. Support blood pressure with IV crystalloid. If significant hypotension, 1 – 2mEq/kg NaHCO₃ is indicated. If refractory, use noradrenalin IV infusion.
3. Treat arrhythmias (high risk if QRS >0.1s) with 1 – 2mEq/K NaHCO₃ IV, 1mg/kg Lignocaine IV and synchronised cardioversion.
4. Treat seizures (high risk if QRS >0.1s) with benzodiazepines. The role of phenytoin is controversial and not recommended by some authors.
5. 1 – 2mEq/K NaHCO₃ IV rapidly narrows the QRS complex width and reduces the risk of arrhythmias
6. Once the airway is secured, consider gastric lavage as the antimuscarinic effect often results in delayed gastric emptying and absorption of further drug can therefore be reduced
7. Consider using 20% intralipid IV, as TCADs are lipophilic
8. Full monitoring while QRS remains prolonged
9. If intentional, will require psychiatric review, once acute toxicity has resolved



Description

Broad complex, regular tachycardia

Prolonged QT interval (Black bar)

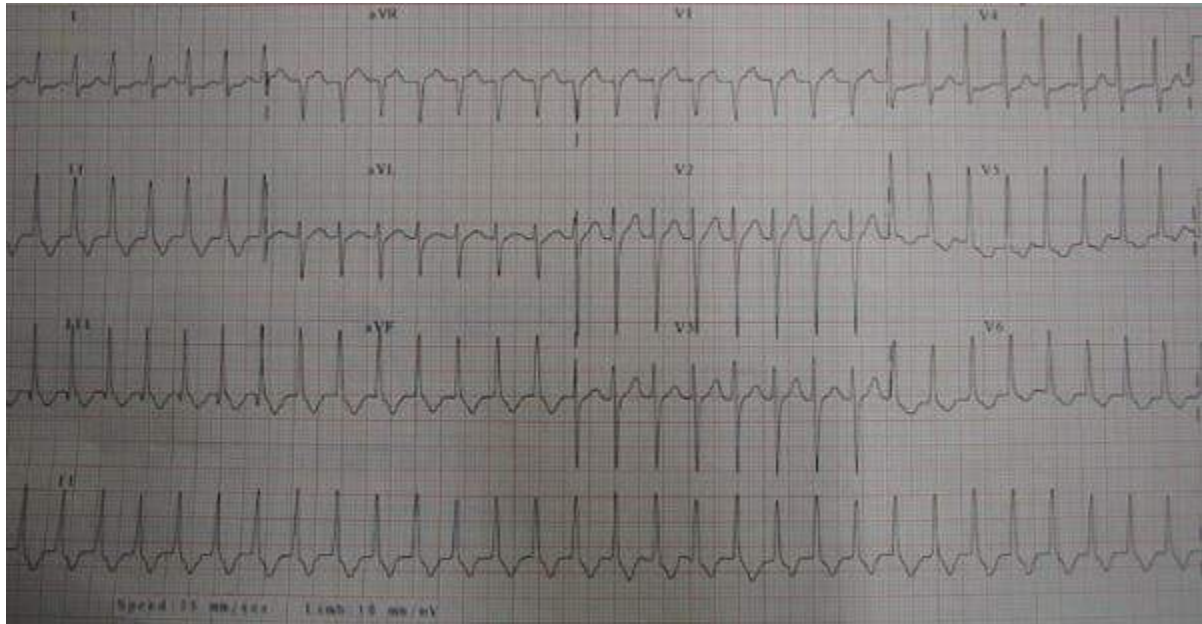
Deep S-wave in lead I (Blue ellipse)

Prominent R-wave in aVR or V1 (Pink ellipse)

ECG – Case 6

Question:

List 4 methods of treating this arrhythmia.



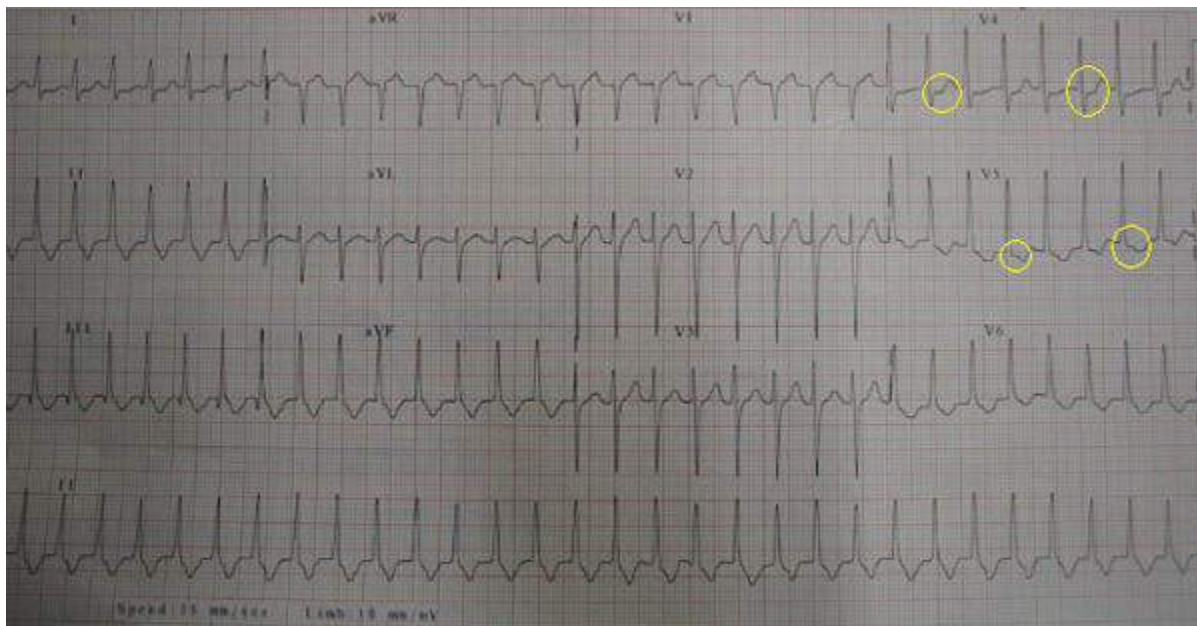
Answer:

Diagnosis = SVT (AVNRT)

Treatment

- Synchronised cardioversion (If hypotensive, evidence of cardiac ischaemia, evidence of heart failure or failed drug therapy. Potentially harmful if the SVT is due to digoxin toxicity.)
- Vagal manoeuvre – e.g. carotid massage, facial cold water immersion, Valsalva manoeuvre
- Adenosine IV in increments of 6mg to a maximum of 18mg, as a rapid bolus
- Verapamil 5mg IV over 1 – 2 minutes, unless accessory pathway (AVRT – see below) suspected

Additional alternatives include IV propranolol 0.5 – 1mg IV over 1 minute repeated every 5 minutes, metoprolol 5mg over 1 – 2 minutes every 5 minutes and external overdrive pacing at the SVT rate + 40bpm for 10 beats at 120mA.



Description

A regular narrow complex tachycardia with a ventricular rate of approximately 180bpm (therefore less likely to be atrial flutter, which usually runs at 150 or 300bpm)

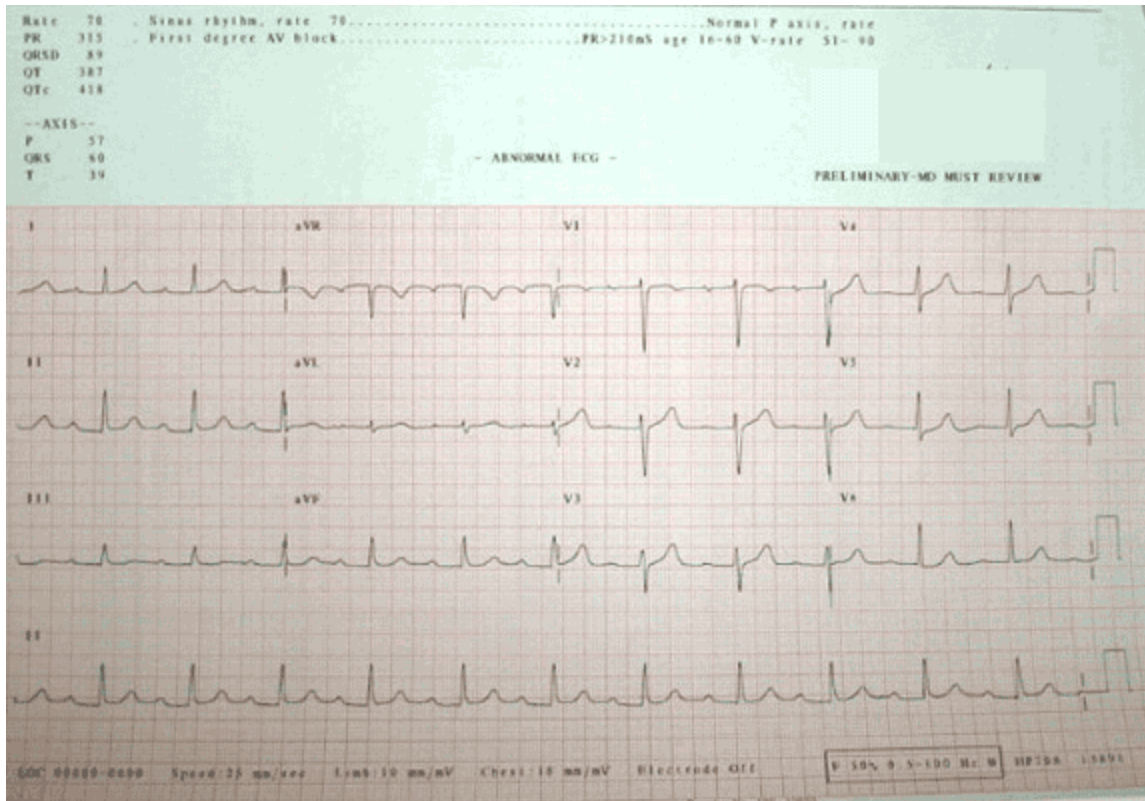
There are no visible P waves, suggesting that this is an AV nodal re-entrant (AVNRT) SVT.

An AV re-entrant (AVRT) SVT is composed of an accessory pathway and the AV node, which requires the electrical impulse to travel between the two; orthodromic if it travels from AV node to accessory pathway and antidromic in the opposite direction. The resultant P wave is therefore usually seen after the QRS complex; i.e. the retrograde P wave, which shows up as a small negative deflection between the QRS complex and the T wave, or as a dent in the upstroke of the T wave. However, it may be difficult to confidently differentiate an AVRT from an AVNRT and it would make you less enthusiastic about using verapamil for chemical cardioversion.

ECG – Case 1

Question:

List 4 conditions associated with this abnormality



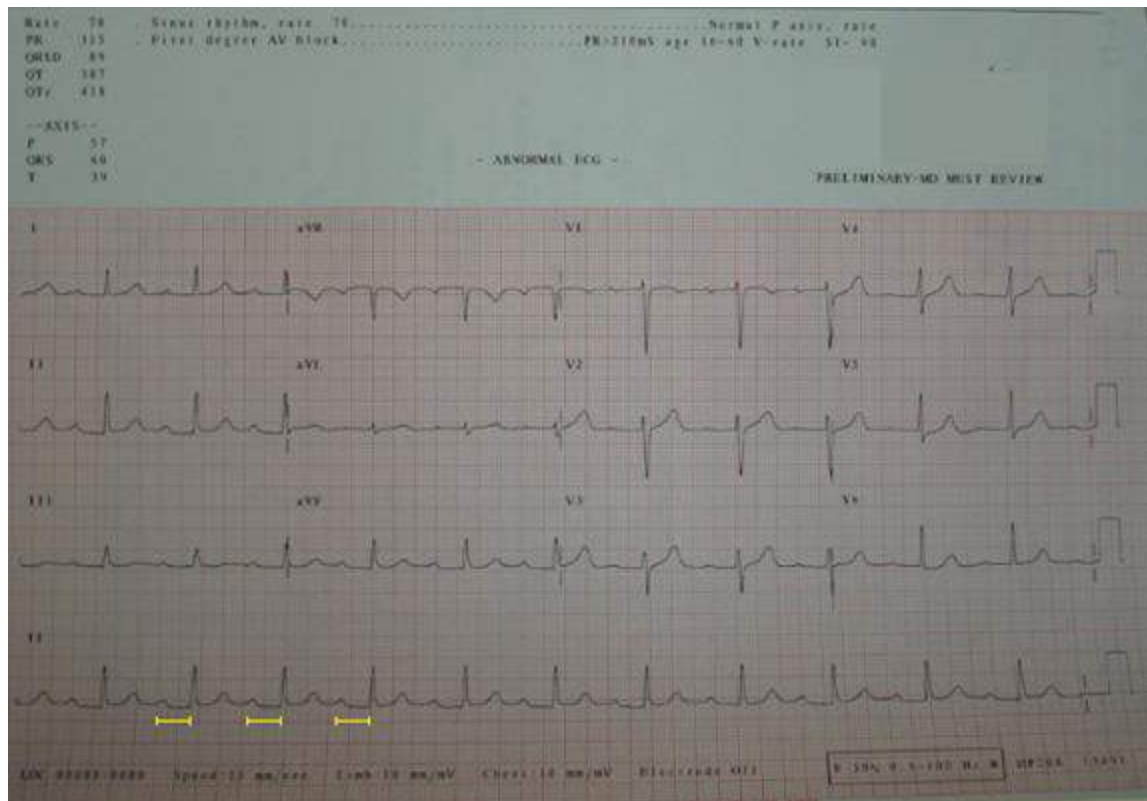
Answer:

Diagnosis = 1st degree heart block

Associated conditions

1. Normal variant
2. Inferior AMI
3. Myocarditis
4. Digoxin toxicity

Also, any cause of increased vagal tone



Rate = 76bpm.

Normal axis.

Sinus rhythm with prolonged PR segment (8 small boxes, or 0.32s – yellow bars)

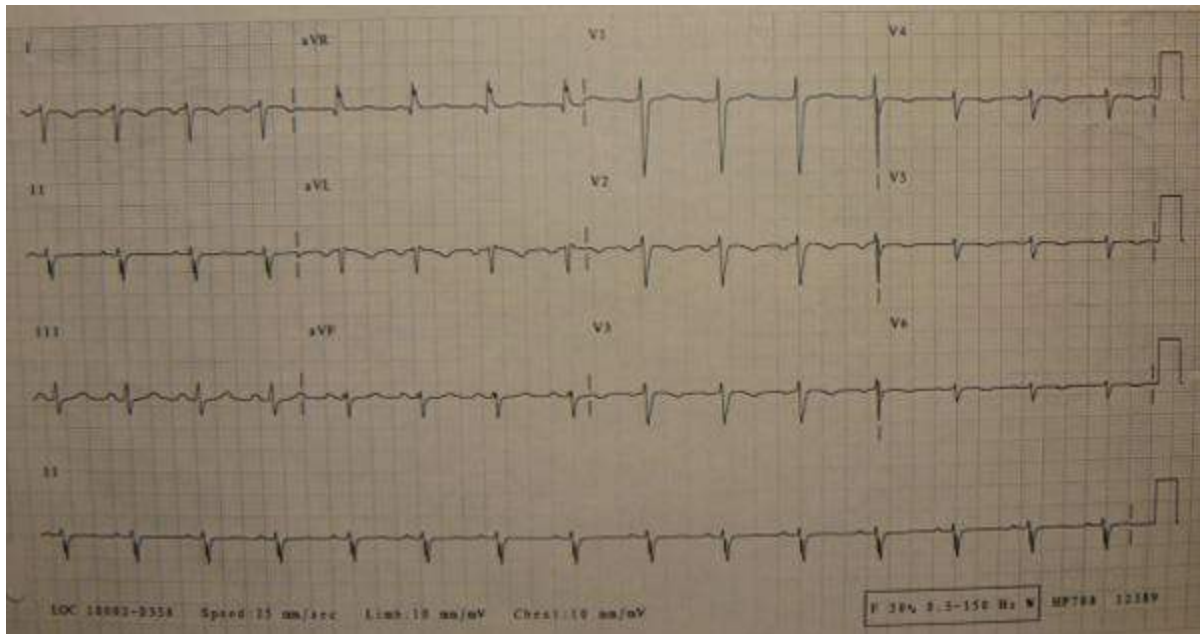
Normal QRS and QT duration

Normal P, QRS and T wave morphology

ECG – Case 9

Question:

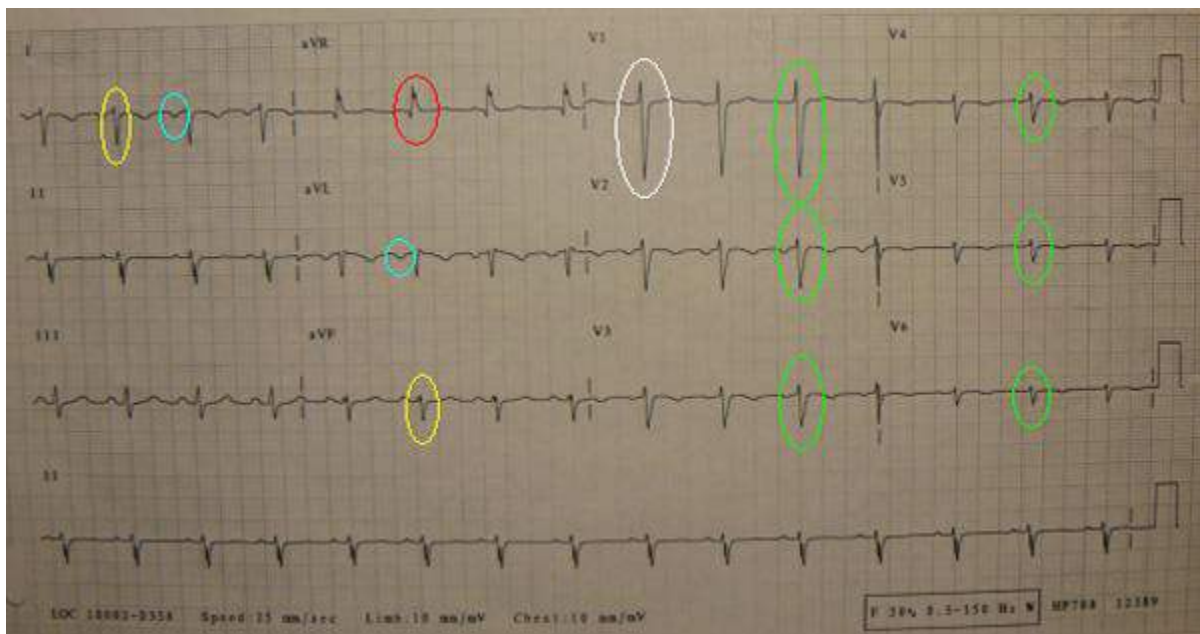
What condition is reflected in this ECG? How would you confirm your suspicion?



Answer:

Diagnosis = Dextrocardia

Confirmation by either a carefully labelled CXR or a transthoracic ECHO.



Description

Extreme right axis (yellow ellipses)

Negative deflection P waves in leads I and aVL (blue ellipses)

QRS in aVR (red ellipse) looks like a normal aVL complex

Presence of an RV1 (white ellipse)

Poor R wave progression from V1 to V6

ECG – Case 7

Question:

Please interpret the sequence of events in this rhythm strip. What underlying ECG deficit would you look for?



Answer:

Diagnosis = VPC resulting in R-on-T induced Torsades de pointes (polymorphic VT) at the start of the upper rhythm strip and subsequent cardioversion near the middle of the lower rhythm strip. There is no evidence of a large voltage spike prior to the cardioversion, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of $MgSO_4$.

I would look for a prolonged QT segment on the post reversion ECG. It is not evident on this strip.



Description

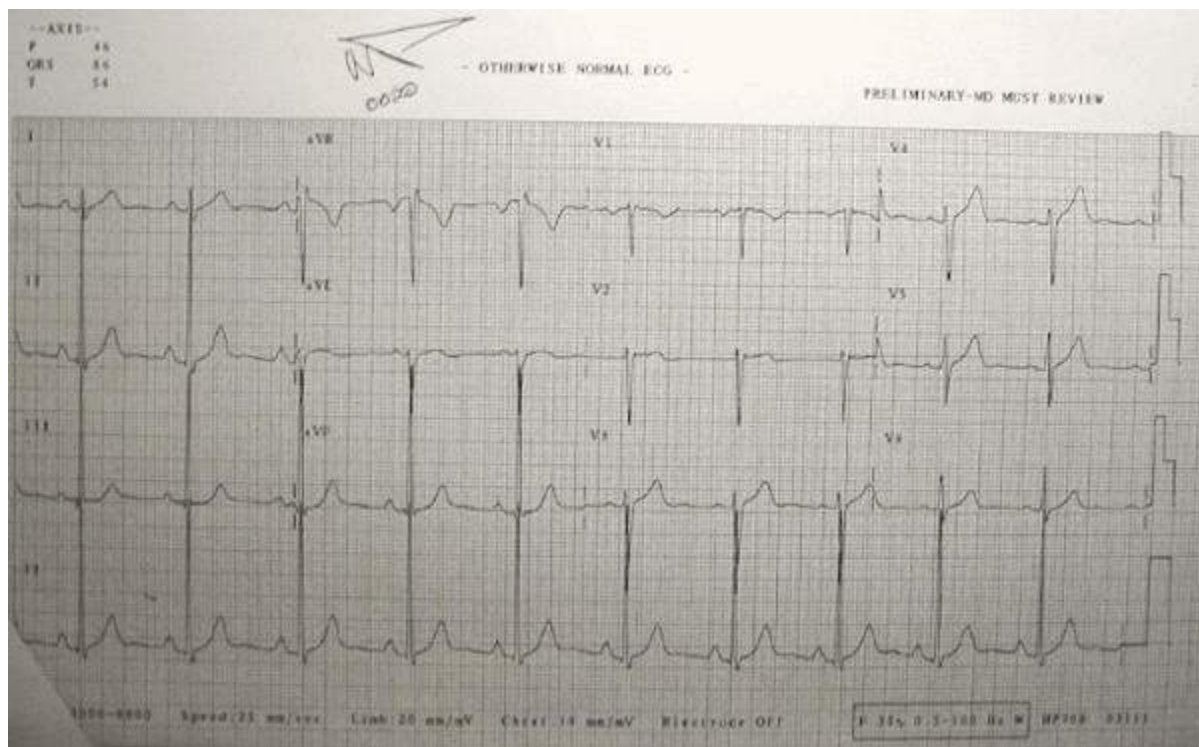
The upper rhythm strip demonstrates a VPC (yellow circle) occurring on top of the T wave of the preceding QRS complex. It probably recurs after the second QRS complex, as polymorphic VT ensues which varies both in the height and width of the complexes.

Midway through the lower rhythm strip, the VT terminates and reverts to a narrow complex rhythm that does not have an obviously prolonged QT segment (See below). At the point that the polymorphic VT terminates (blue circle) there is no evidence of a large voltage spike, suggesting that reversion was achieved either spontaneously or chemically, most likely with the use of MgSO₄.

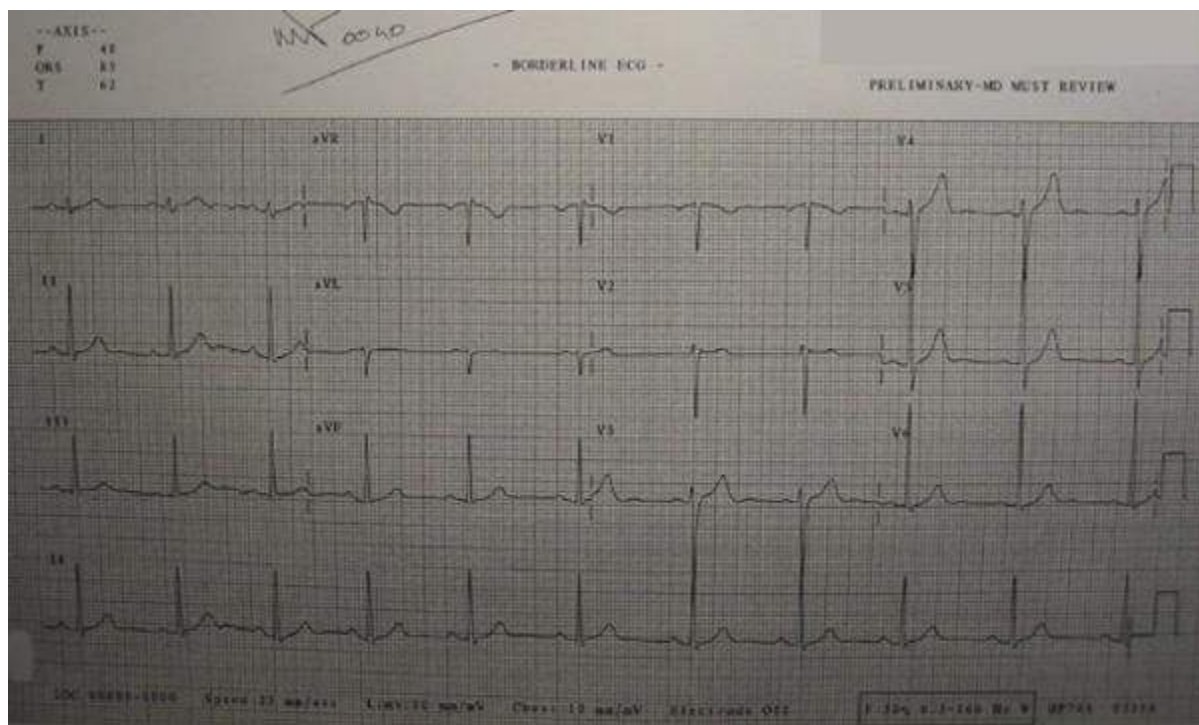
ECG – Case 2

Question:

- Describe the features of this ECG



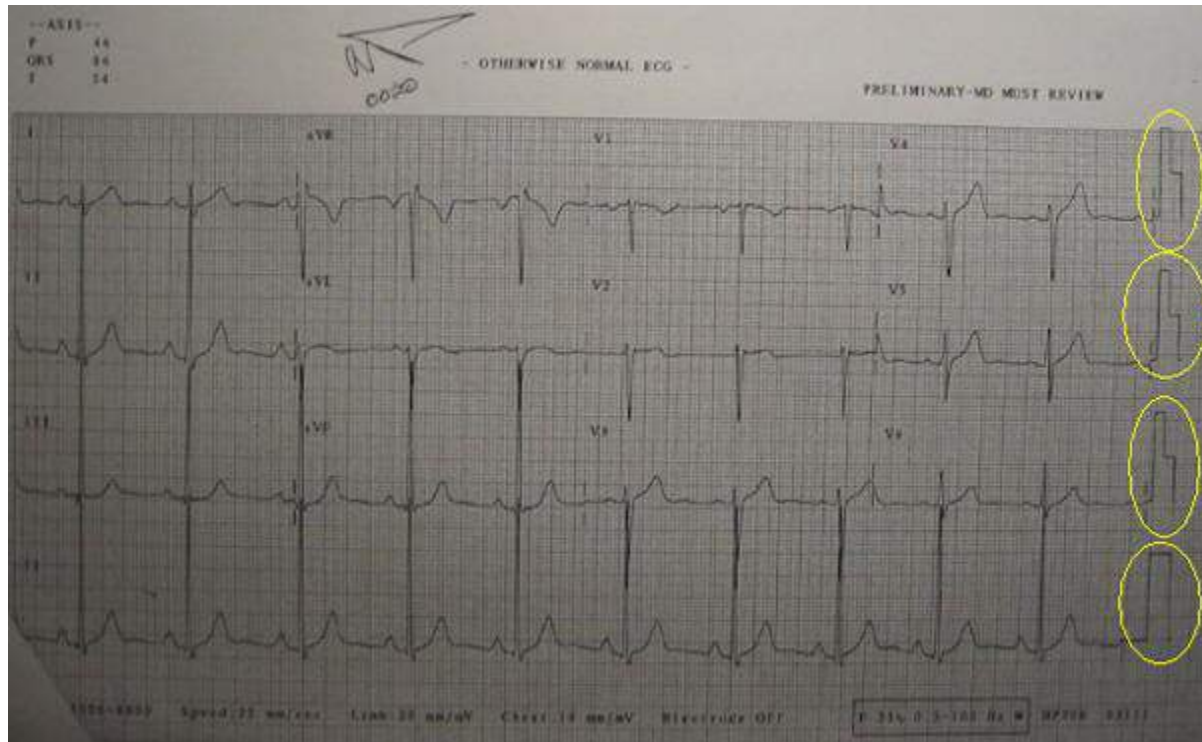
b) With the voltage calibration corrected, describe the ECG as shown below



Answer:

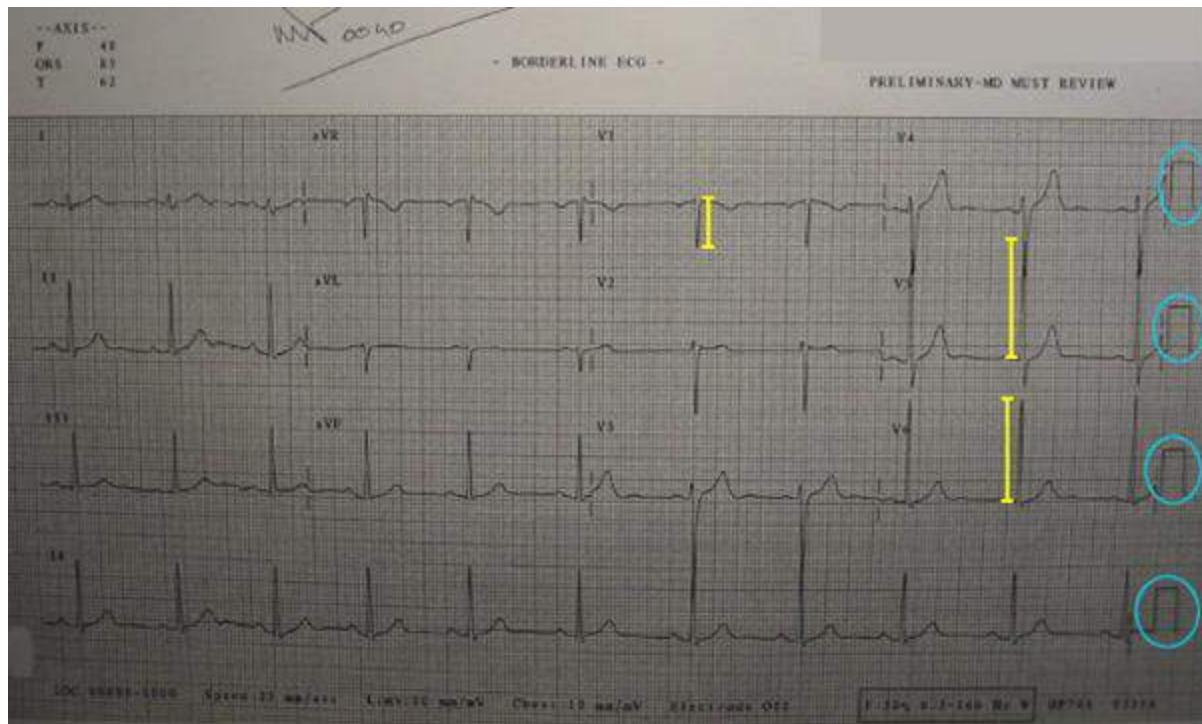
Description: There is a voltage calibration error (yellow circles), resulting in distortion of the height of the P and T waves and the QRS complexes. The paper speed is correct (25mm/sec), so the rhythm is sinus at about 60bpm.

Diagnosis = Voltage calibration error



Diagnosis = Normal ECG

Description: With correction of the voltage calibration (blue circles), the ECG is suggestive of left ventricular hypertrophy (yellow bars). However, it lacks a left axis deviation and fails to meet any of the voltage criteria (Sokolow-Lyon indices, Romhilt-Estes point score system, Cornell voltage criteria) for true LVH.



Voltage criteria for LVH

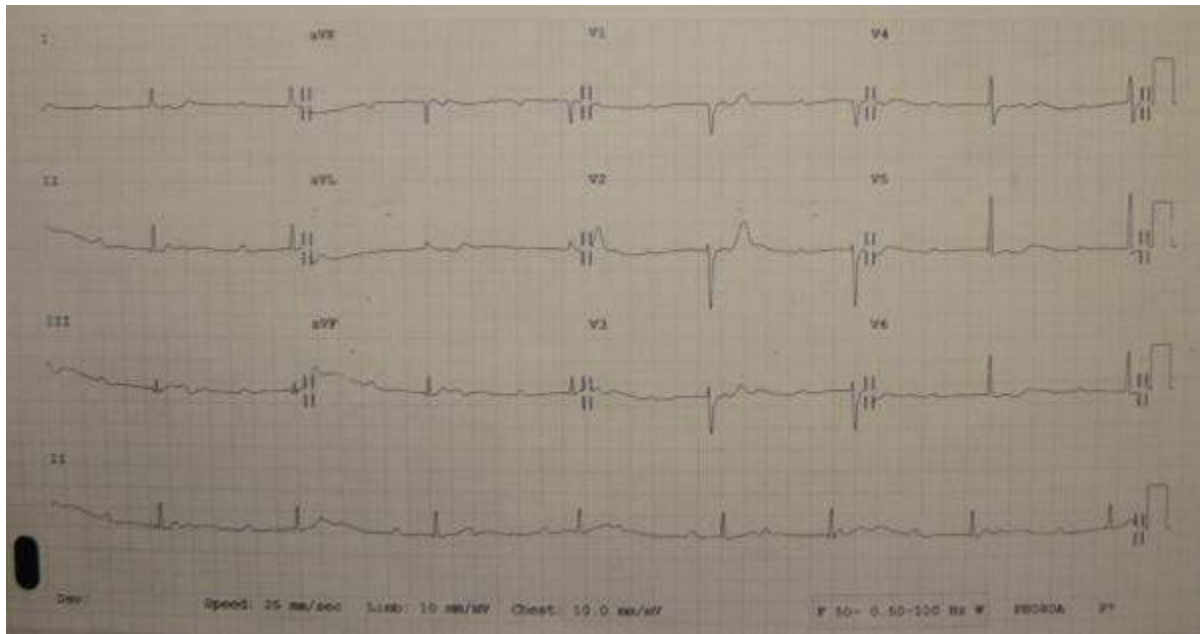
There are a variety of voltage criteria used to identify LVH, with specificities that are generally good (86 - 100%) but with poor sensitivities (1.5 - 55%). They include:

- S wave in V1 + R wave in V5 or V6 > 35 mm if age > 40yo, > 40 mm if age 30 to 40yo, > 60 mm if age 16 to 30yo (Sokolow-Lyon indices; sensitivity 40%, specificity 95%) (yellow bars).
- R wave in I + S wave in III > 25mm
- R wave in aVL > 11mm
- R wave in aVF > 20mm
- R wave in V5 or V6 > 26mm

ECG – Case 10

Question:

What physiological disturbance might you expect as a result of this ECG? What definitive intervention may be required?

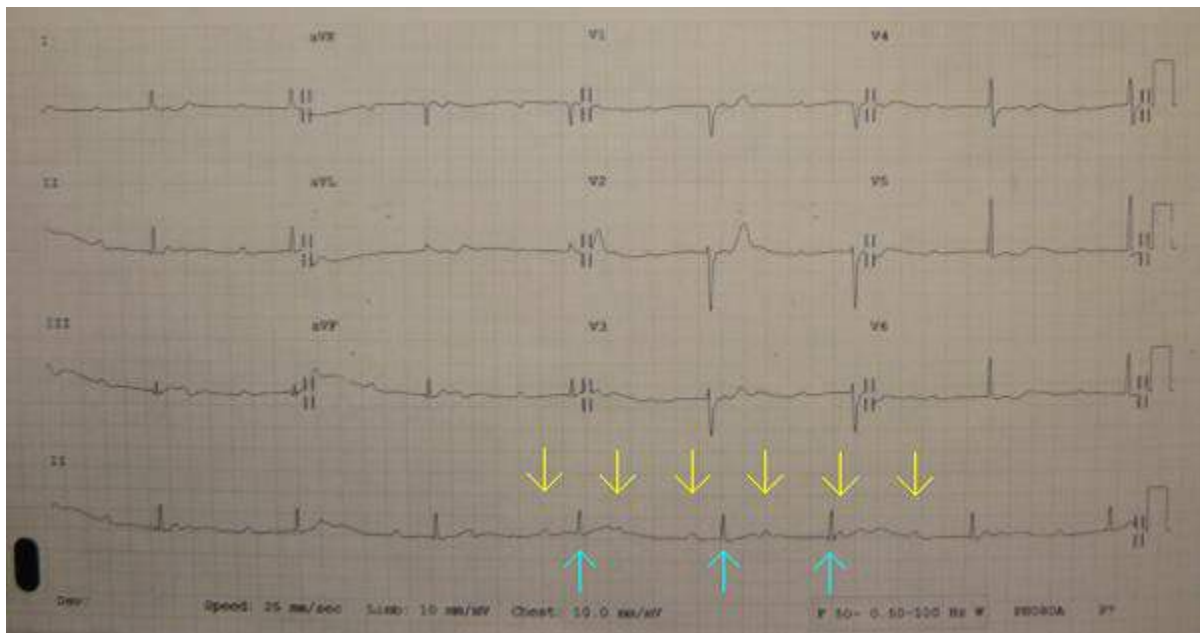


Answer:

Diagnosis = Complete heart block

Physiological disturbance: Hypotension

Intervention: Permanent pacemaker



Description

Normal morphology P waves occurring at a regular interval (yellow arrows) and independent of the occurrence of QRS complexes (blue arrows)

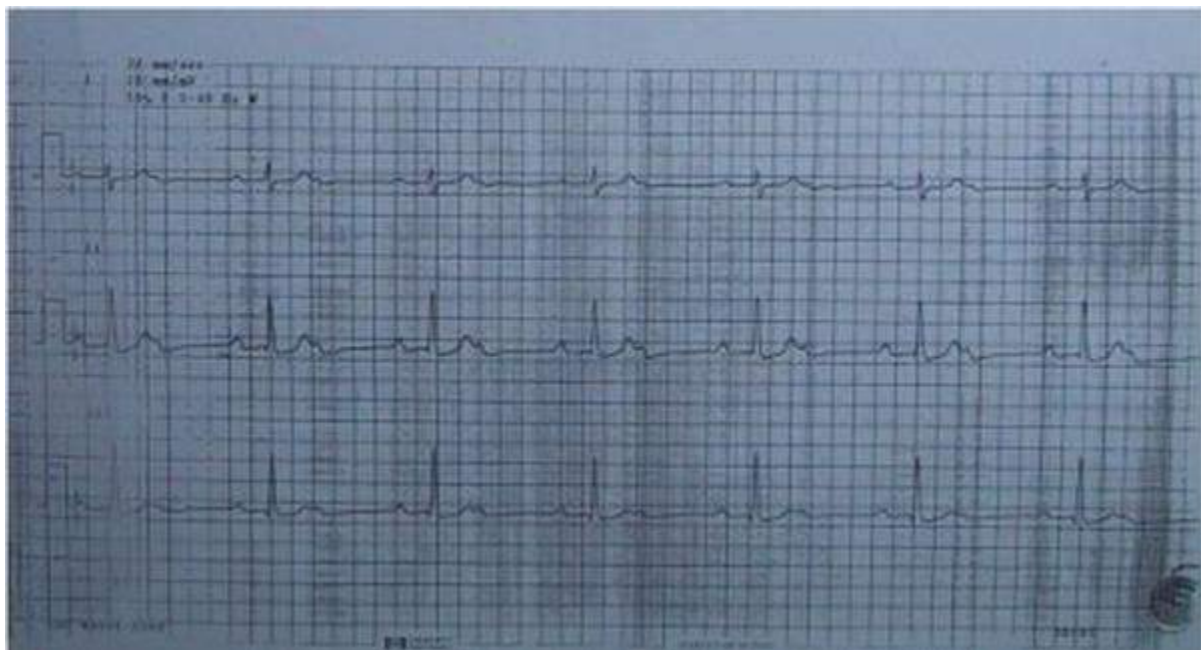
The ventricular rate is approximately 50bpm and is probably junctional in origin (narrow complex)

No evidence of an inferior ischaemic event on this ECG (Always look for this when you identify a heart block pattern!)

ECG – Case 4

Question:

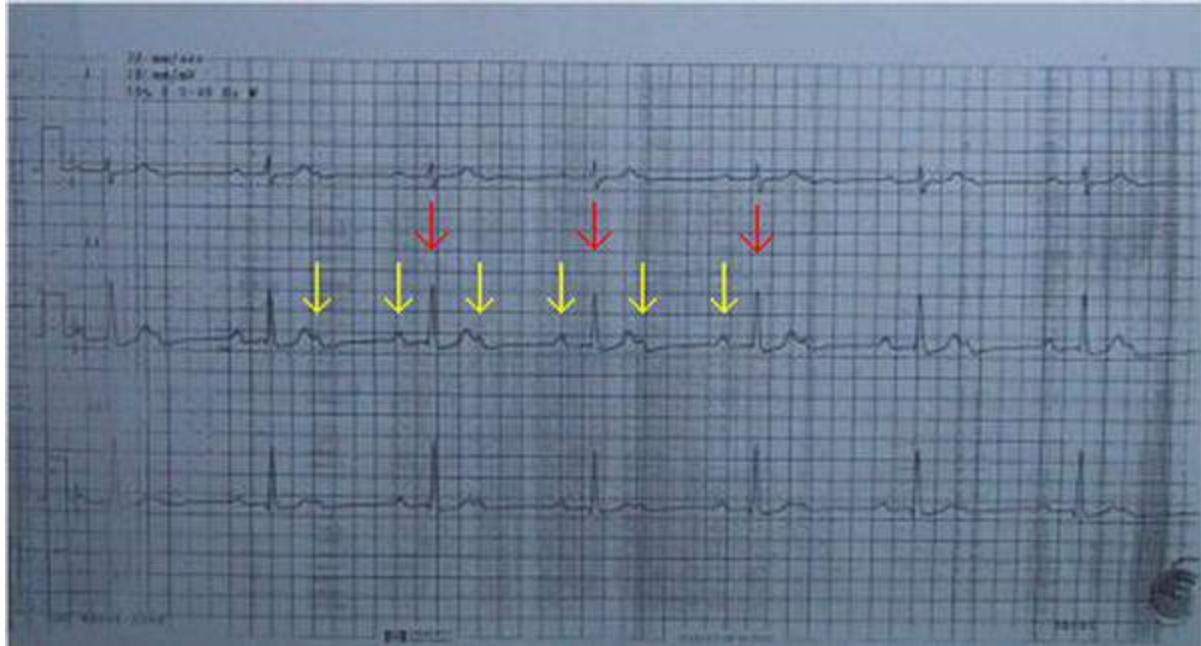
What associated pathology would you check for given the features of this ECG?



Answer:

Diagnosis = Mobitz type II 2nd degree heart block with 2:1 block

Associated pathology: Evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)



Description:

A normal morphology QRS complex (red arrows) follows every second P wave (yellow arrows) at regular intervals.

The P waves are spaced at regular intervals and are of normal morphology (as they originate from the sinus node)

The ventricular rate is approximately 40bpm

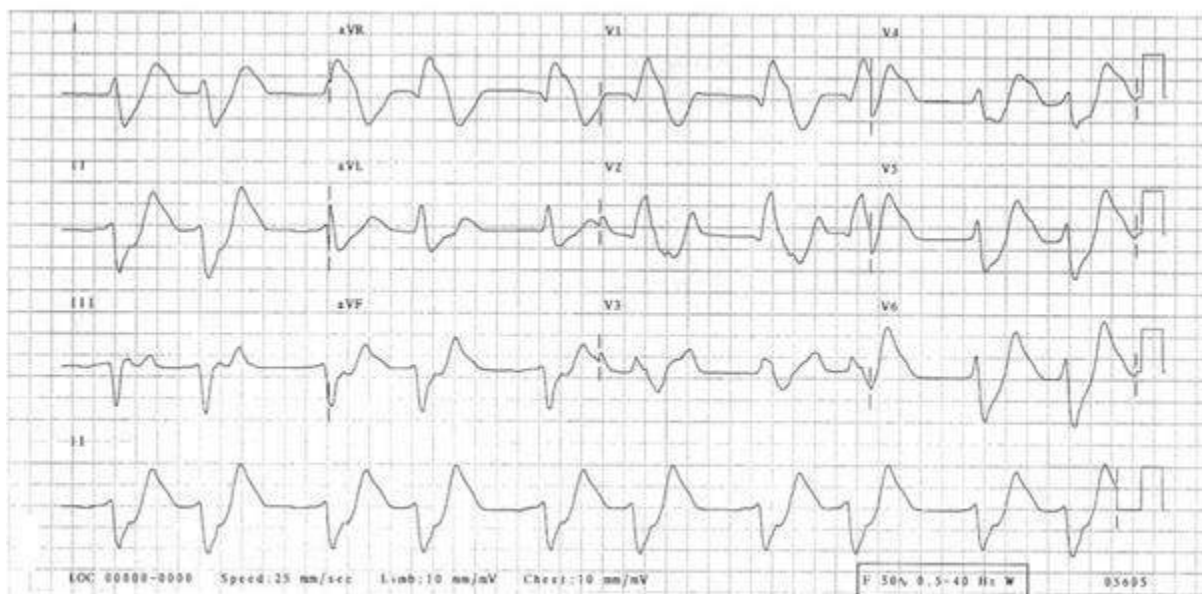
The axis is normal

There is no evidence of inferior ischaemia on this ECG (which you should look for on any ECG demonstrating heart block and vice versa)

ECG – Case 15

Question:

List the therapeutic interventions, along with an indication of time to effect and the mode of effect, for a patient with the following ECG



Answer:

Diagnosis = Hyperkalaemia

Therapeutic strategies

Therapy	Time to effect	Mode of effect
Calcium chloride 10mls 10%	Seconds to minutes	Stabilises myocardium from effect of hyperkalaemia. Avoid if digoxin toxicity suspected
0.5 – 1mEq/kg NaHCO ₃ 8.4% IV	Several minutes	Intracellular K ⁺ shift
50mls 50% Dextrose + 10U Actrapid	20 – 40 minutes	Intracellular K ⁺ shift

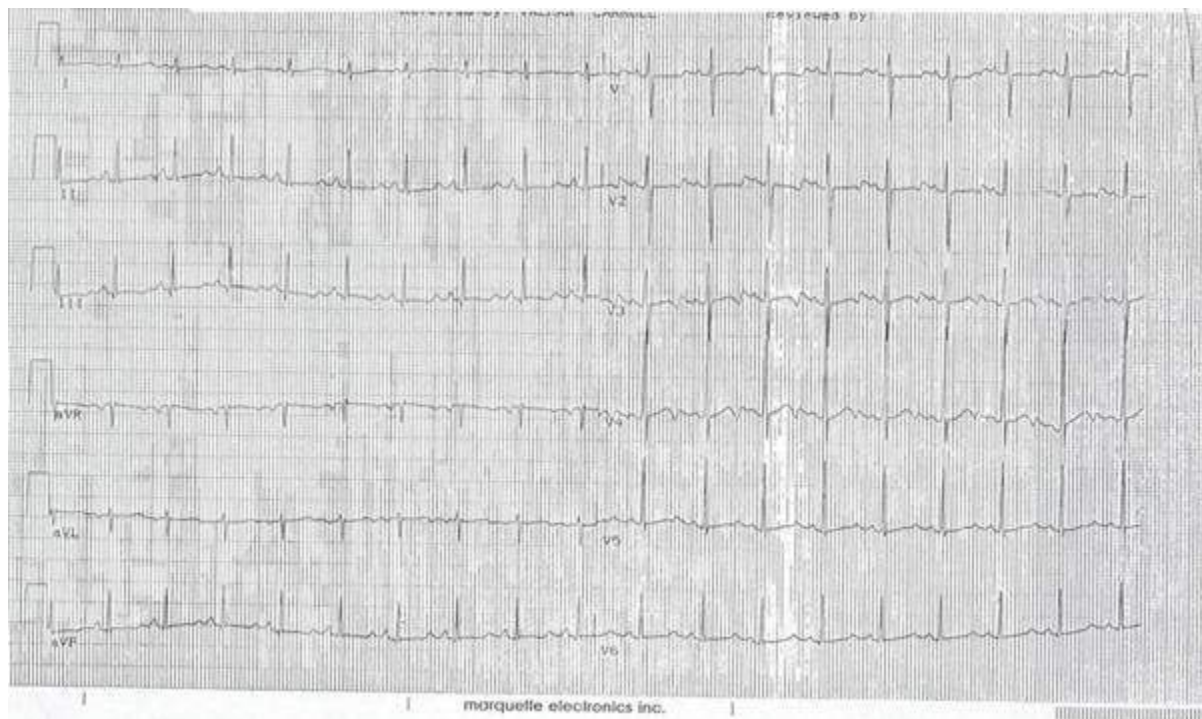
<p>insulin IV</p> <p>(Arguably, if the person is not a diabetic, the dextrose challenge should stimulate sufficient native insulin to achieve the desired effect)</p>		
<p>Continuous nebulised salbutamol</p>	<p>20 – 40 minutes</p>	<p>Intracellular K⁺ shift.</p> <p>(Better efficacy in paediatric population than adults)</p>
<p>Loop diuretic; e.g. frusemide 40 – 120mg IV with IV fluids to cover for the diuresis.</p>	<p>30 – 120 minutes</p>	<p>Enhanced renal excretion of K⁺ (Potassium losing diuretic)</p>
<p>Polystyrene sulfonate salt; e.g. calcium or sodium resonium 30 – 45g</p>	<p>1 – 3 hours</p>	<p>Ion exchange resin that bind K⁺ and enhances GI elimination</p>

PO/PR		
Dialysis; K+ free IHD, SLED, CRRT or peritoneal dialysis	Applied for several hours, but rapidity of effect related to blood flow rate	Transfilter, or transperitoneal, K+ removal

ECG – Case 18

Question:

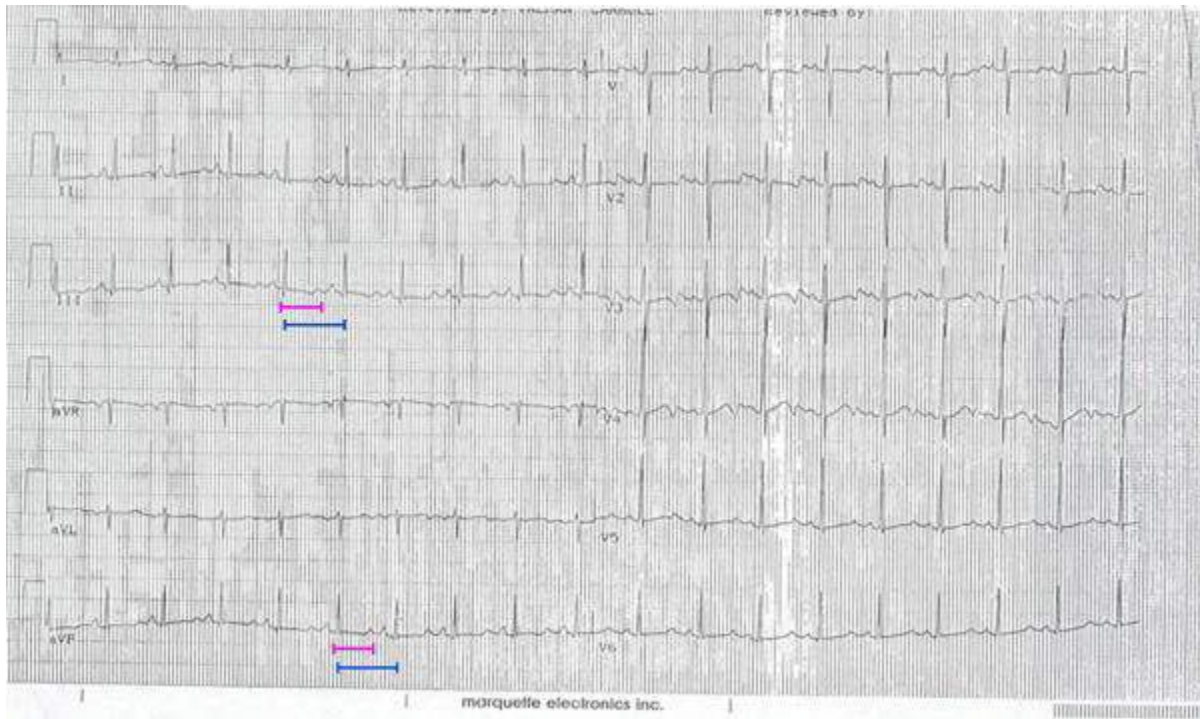
List 7 causes of the following ECG appearance.



Answer:

- Electrolyte disturbances – hypoMg, hypoK, hypoCa
- Medication – Class Ia, Ic and III antiarrhythmics, macrolides,azole antifungals, antipsychotics, antidepressants, antihistamines
- Endocrinopathies – hypothyroidism, phaeochromocytoma
- Cardiac disease – AMI, myocarditis

- Intracranial pathologies – ICH, CVA
- TPN
- Congenital conditions – Romano-Ward syndrome, Jervelle-Lang-Nielson syndrome



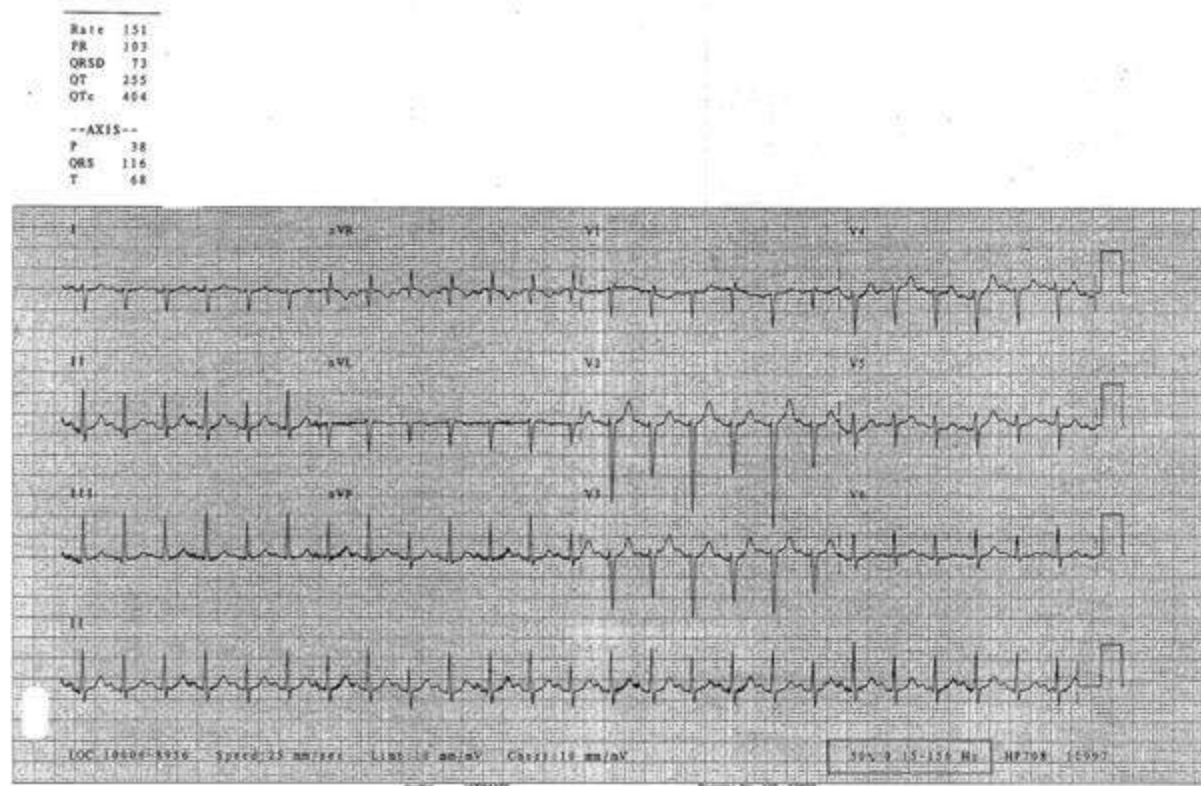
Description

If numerical data is available at the top of the ECG, one of the few to be taken on faith is the QTc, as it is tricky to calculate Bazett's formula under exam conditions. The normal QTc is < 440mSec. Alternatively, visually checking to see if the QT interval (Pink bar) appears to occupy more than half of the R-R interval (Blue bar) is a valid estimate of prolongation.

ECG – Case 13

Question:

How would you confirm the diagnosis? What therapeutic intervention would you consider for a hypotensive patient with the following ECG?

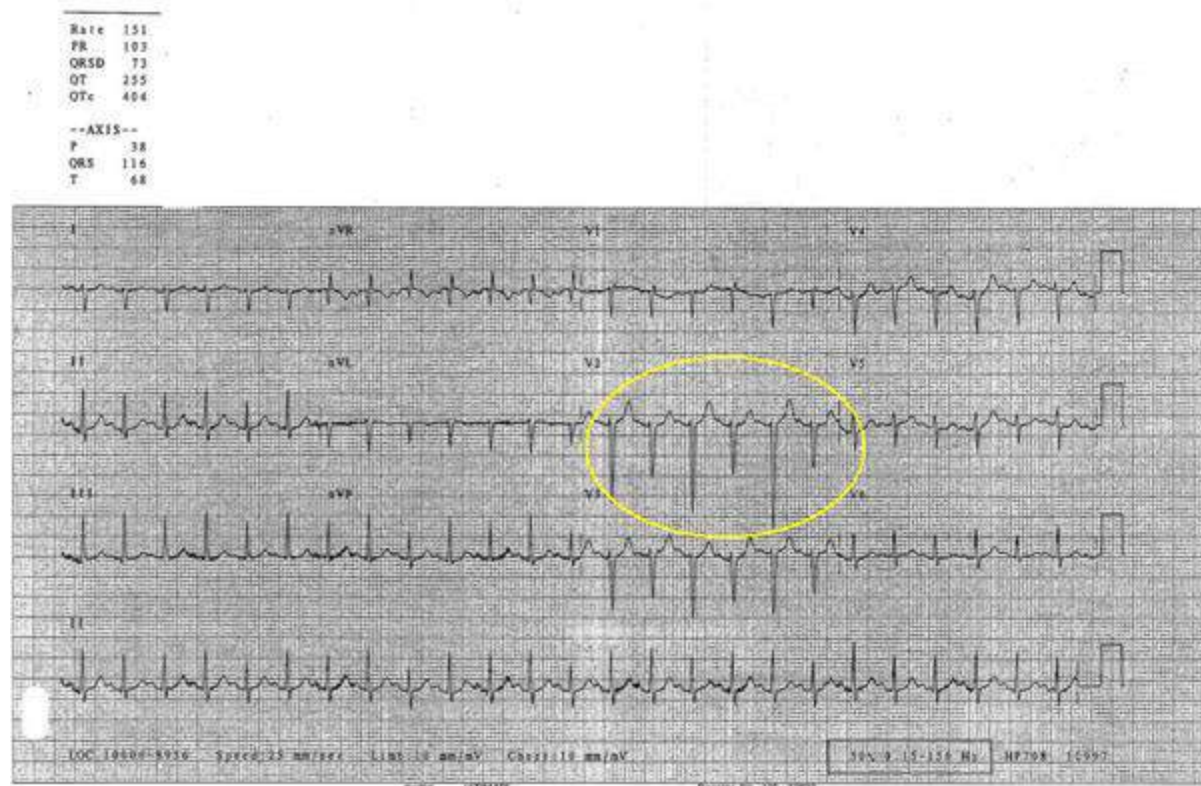


Answer:

Diagnosis = Electrical alternans, pathognomonic of a pericardial effusion

Confirmatory investigation: Transthoracic ECHO

Therapeutic intervention: Pericardiocentesis. If recurrent, a pericardial window may be required.



Description

Sinus tachycardia at approximately 150bpm with a rightward axis

Electrical alternans is demonstrated most clearly in leads V3 (yellow ellipse) and V4

The PR and QT segments are of normal duration

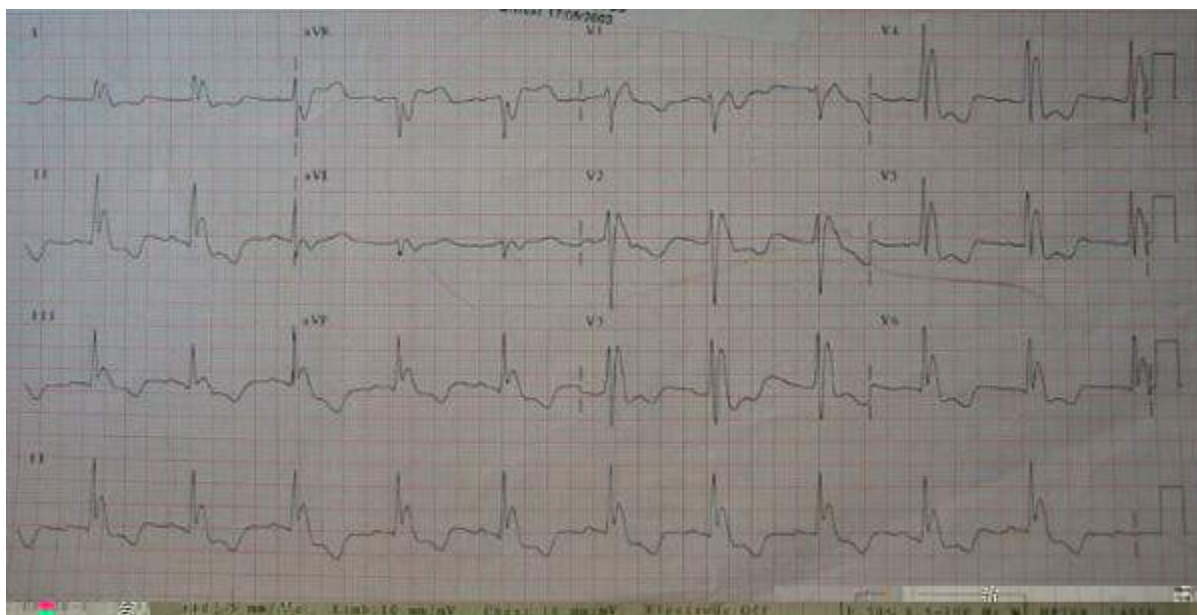
The QRS is narrow and of normal morphology

There are no ischaemic features

ECG – Case 3

Question:

List 3 measures that are used to manage the condition indicated by the following ECG.



Answer:

Diagnosis = Hypothermia

Management:

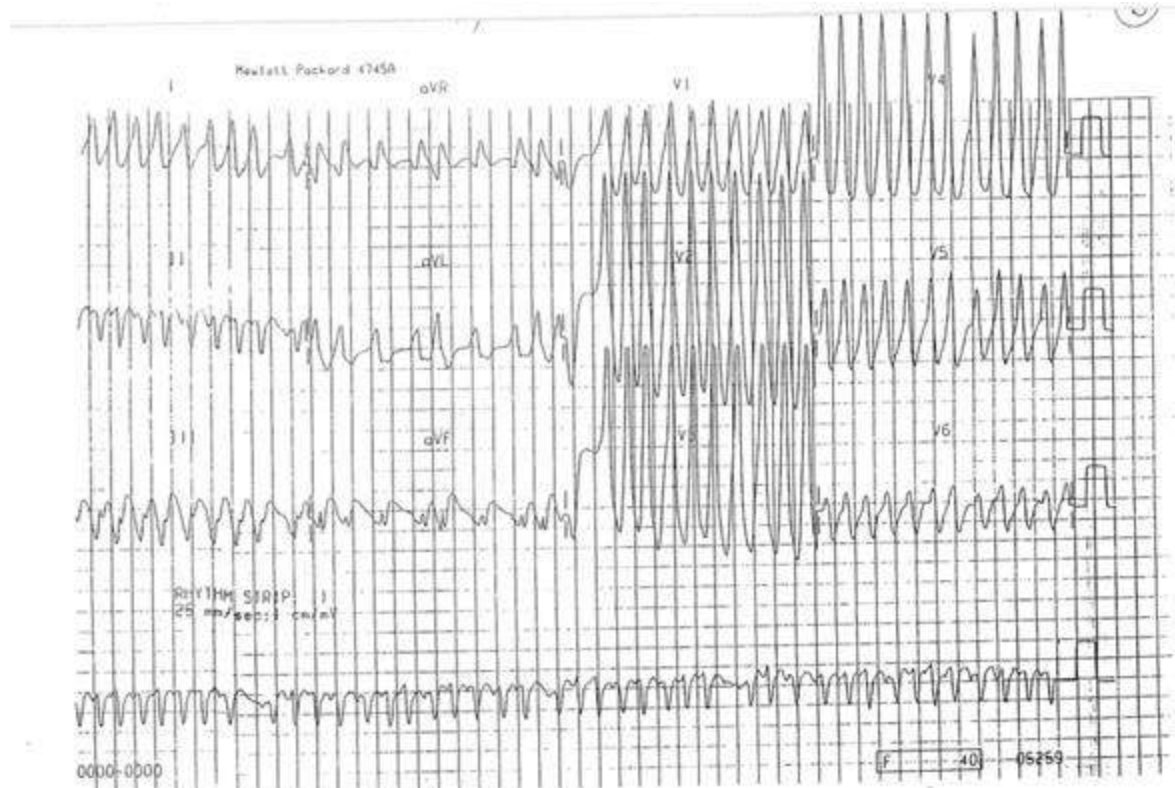
1. Warm air blanket; e.g. Bair hugger
2. Warmed IV fluids
3. Warmed, humidified oxygen

Depending upon the severity of the hypothermia and the stability of the patient's condition, additional therapeutic modalities include warm fluid gastric lavage, warm fluid bladder irrigation, warm fluid peritoneal lavage, dialysis, endovascular warming catheter and cardiopulmonary bypass.

ECG – Case 17

Question:

What are the treatment options for a normotensive patient with this ECG?



Answer:

Diagnosis = Wolff-Parkinson-White syndrome in atrial fibrillation with ultrarapid ventricular response

Treatment options:

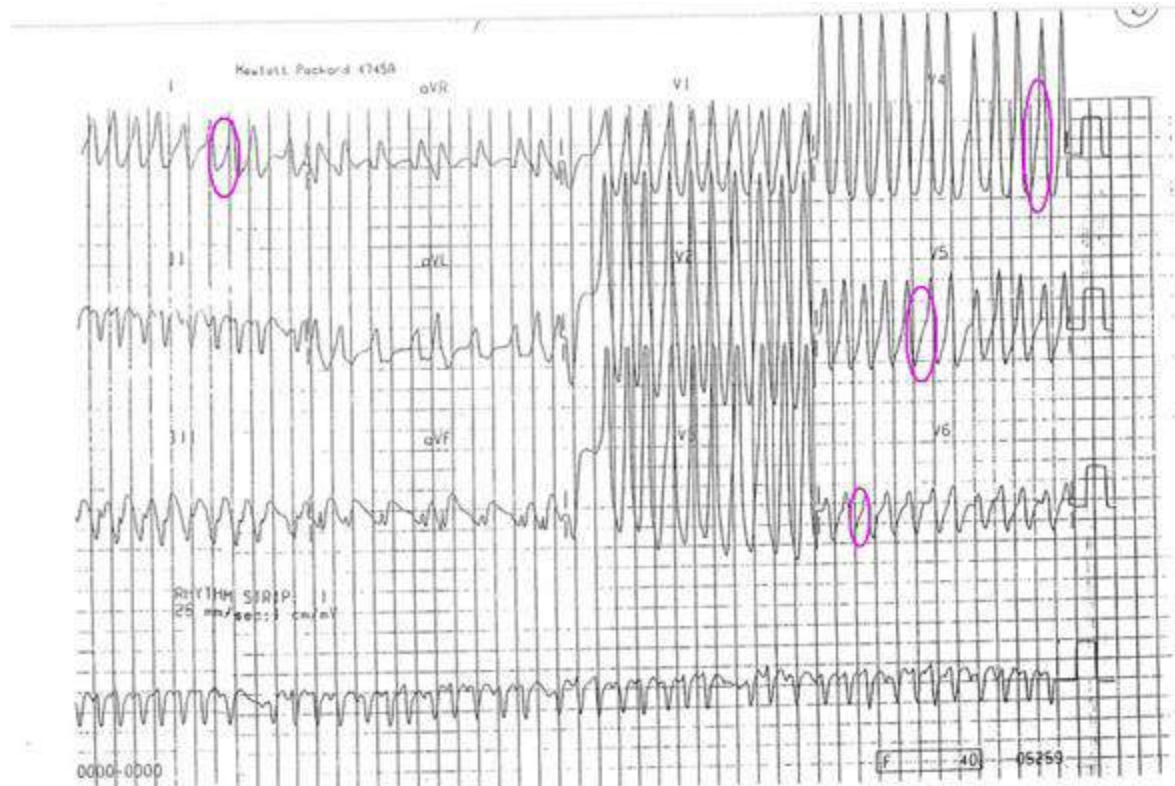
Pharmacological

1. Amiodarone
2. Procainamide
3. Flecainide

Electrical

1. Synchronised cardioversion

Avoid AV node blockers (verapamil, digoxin and β -blockers) which may accelerate the tachyarrhythmia



Description

Irregular tachycardia at approximately 300bpm

Slurred upstroke at the start of the QRS complex visible in several leads (Pink ellipses)

Difficult to determine the type (A-E) and therefore the location of the accessory tract, due to the rapidity of the tachycardia on this ECG. Obtaining a repeat ECG after the rate has been slowed would help.

Imaging data – Case 30

Question:

What is the likely cause of the right lung “white-out”?

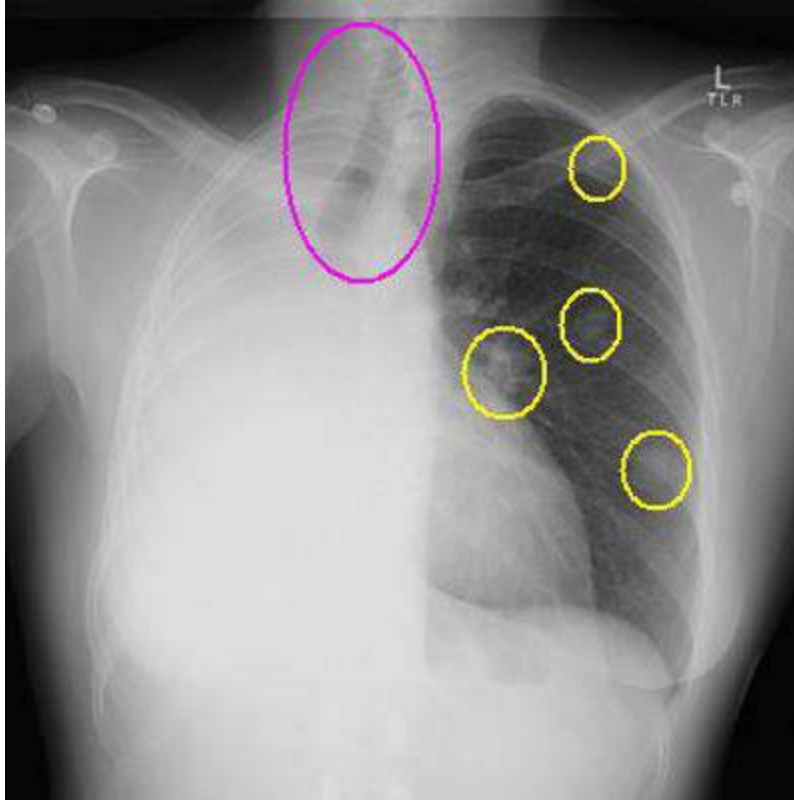


Answer:

Malignant disease; more likely to be metastatic

Description

The trachea (Pink ellipse) is deviated to the side of the lesion consistent with collapse. There is no evidence of previous surgical clips or staples suggesting a pneumonectomy. There are no air bronchograms to indicate consolidation. There is a “cut off” of air in the right main bronchus consistent with an endobronchial obstructive lesion. There are several well-defined opacities in the left lung (Yellow ellipses). Malignant disease would tie all of the appearances together. Look for bone lesions (None on this film.) This patient had a primary lung cancer with metastases.



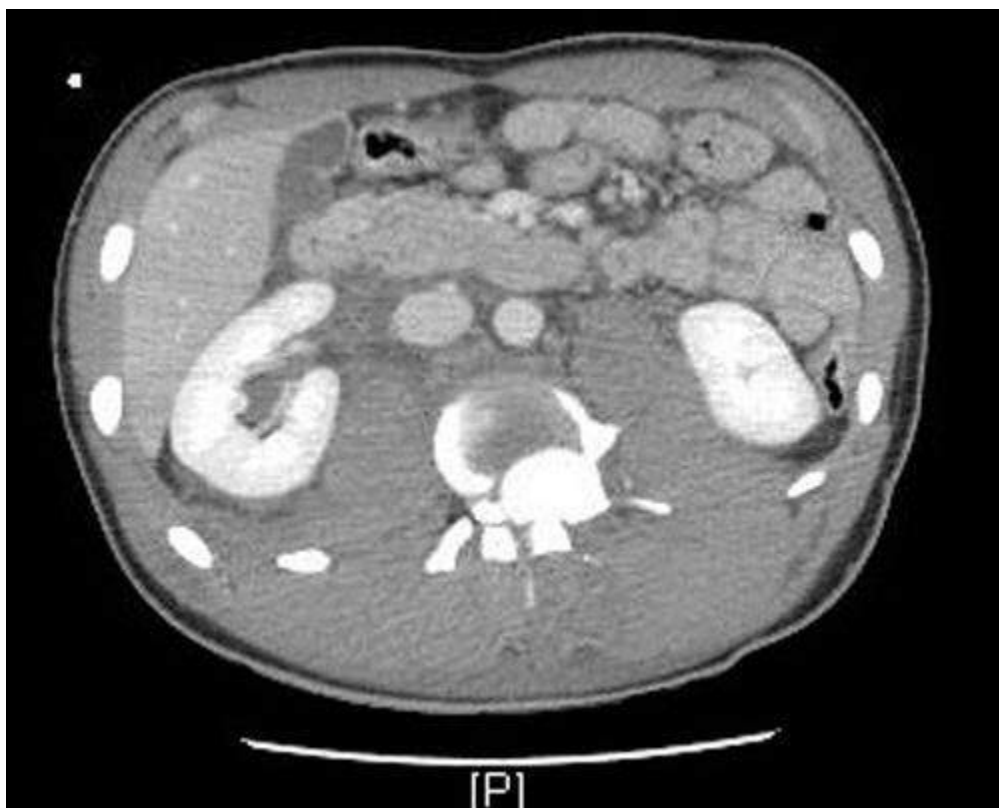
Imaging data – Case 8

Question:

This 50 year old man was a backseat restrained passenger traveling in a car that collided with a tree at speed. He suffered multiple injuries and on the basis of his imaging below what would expect to find on clinical examination? What associated injury would you suspect?



(A)



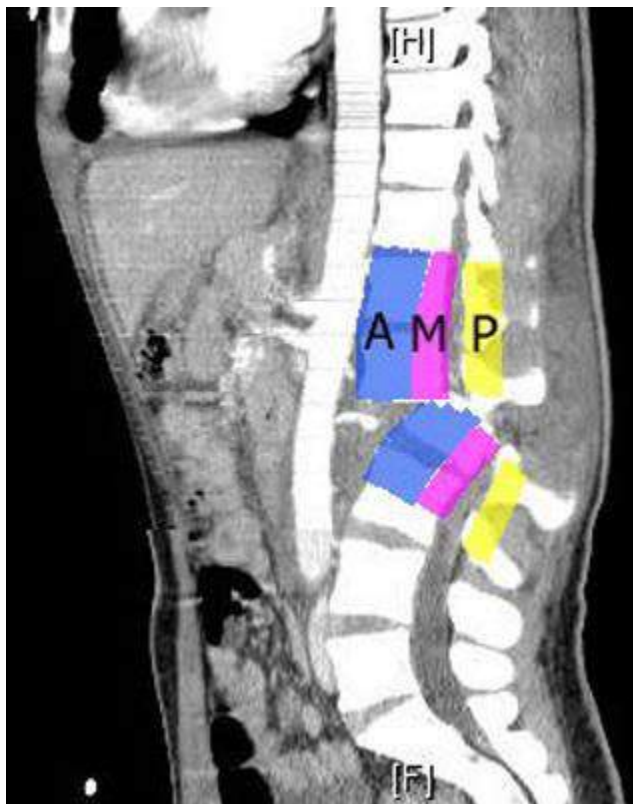
(B)

Answer:

The CT scans show a severe comminuted three column fracture dislocation of L2 classic for a seatbelt injury.

Injuries to L2 frequently damage the conus medullaris with the main clinical findings being lower limb paresis, bilateral preservation of the knee jerks, loss of ankle jerks, sensory disturbance localised to the perianal area, reduced anal tone and urinary retention. This should be differentiated from the cauda equina syndrome which describes lesions below this level.

The classically associated injury is a duodenal perforation.



(A)

A = Anterior column

M = Middle column

P = Posterior column



(B)

P = Paraspinal muscle

V = IVC

A = Aorta

Arrows = haematoma margins

Imaging data – Case 21

Question:

This elderly patient presented with severe abdominal pain. Their past history included chronic atrial fibrillation, hypertension and hypercholesterolaemia. Name 5 abnormalities. What is the most likely cause?



Answer:

Loops of thickened bowel wall (Pink arrows)

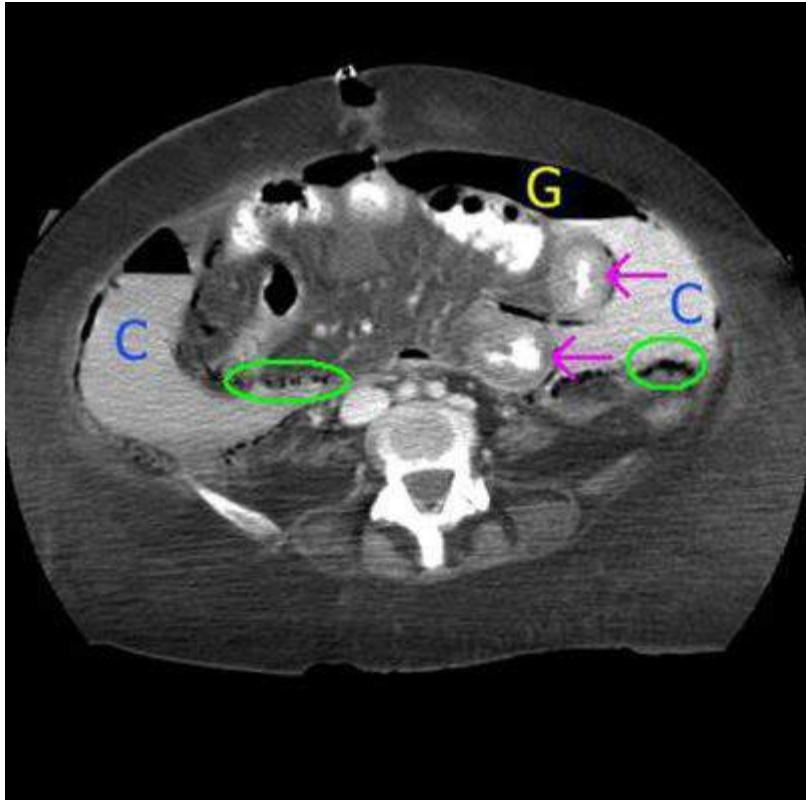
Gas in the bowel wall (pneumatosis intestinalis – Green ellipses)

Mesenteric fat stranding

Free contrast outside the bowel wall (C)

Free gas outside the bowel wall (G)

A unifying diagnosis would be ischaemic bowel with necrosis and perforation secondary to an embolic event complicating their AF.



Imaging data – Case 22

Question:

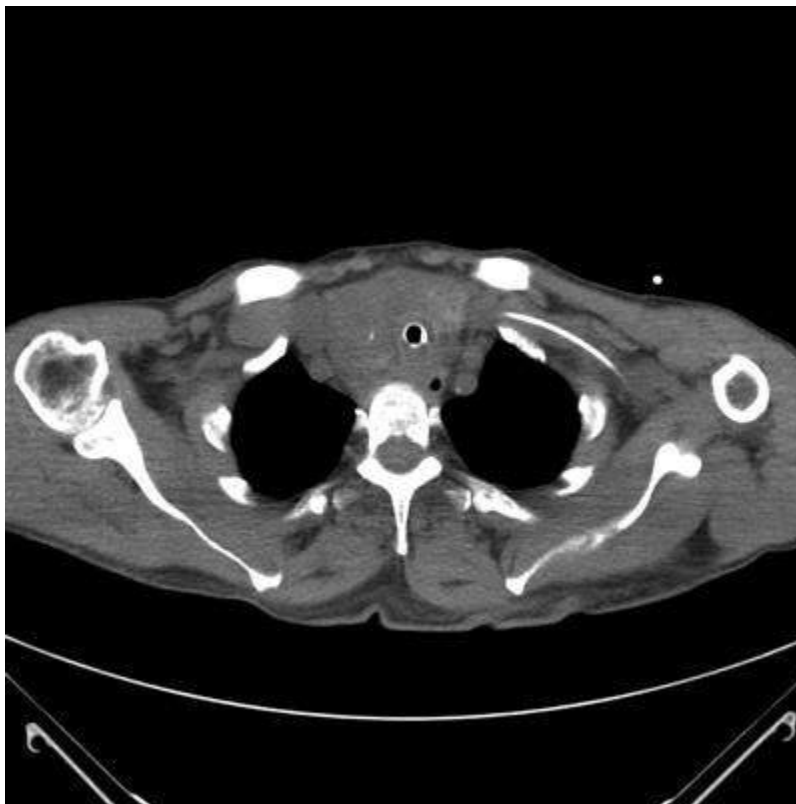
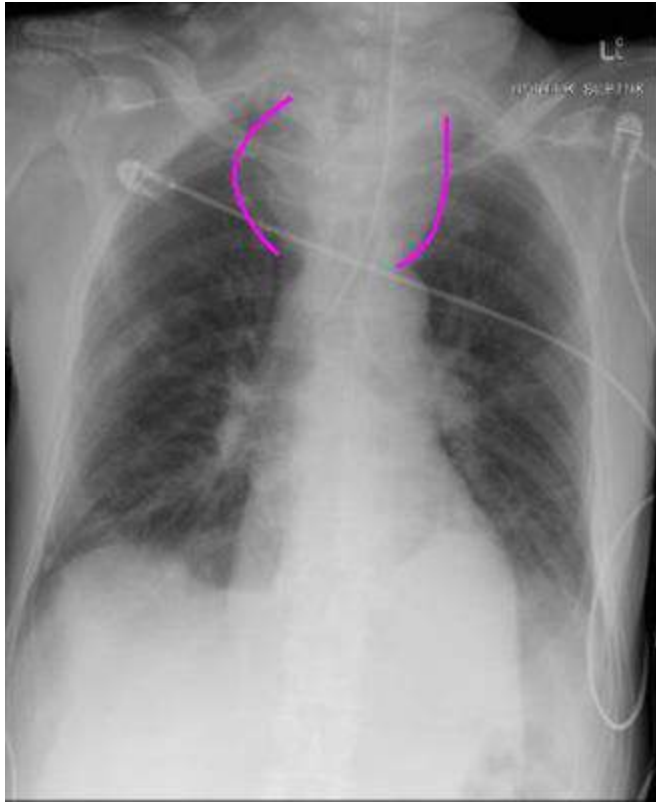
This patient presented with dyspnoea and required intubation for respiratory distress. The intubation was difficult. Identify a cause for these events?



Answer:

There is an abnormal upper mediastinal soft tissue opacity (Pink margins). The endotracheal tube appears deviated to the patients left. The lung fields do not show a gross pathology that would explain the dyspnoea. The heart size appears normal. Tracheal compression from a mass lesion is a likely cause of the problems.

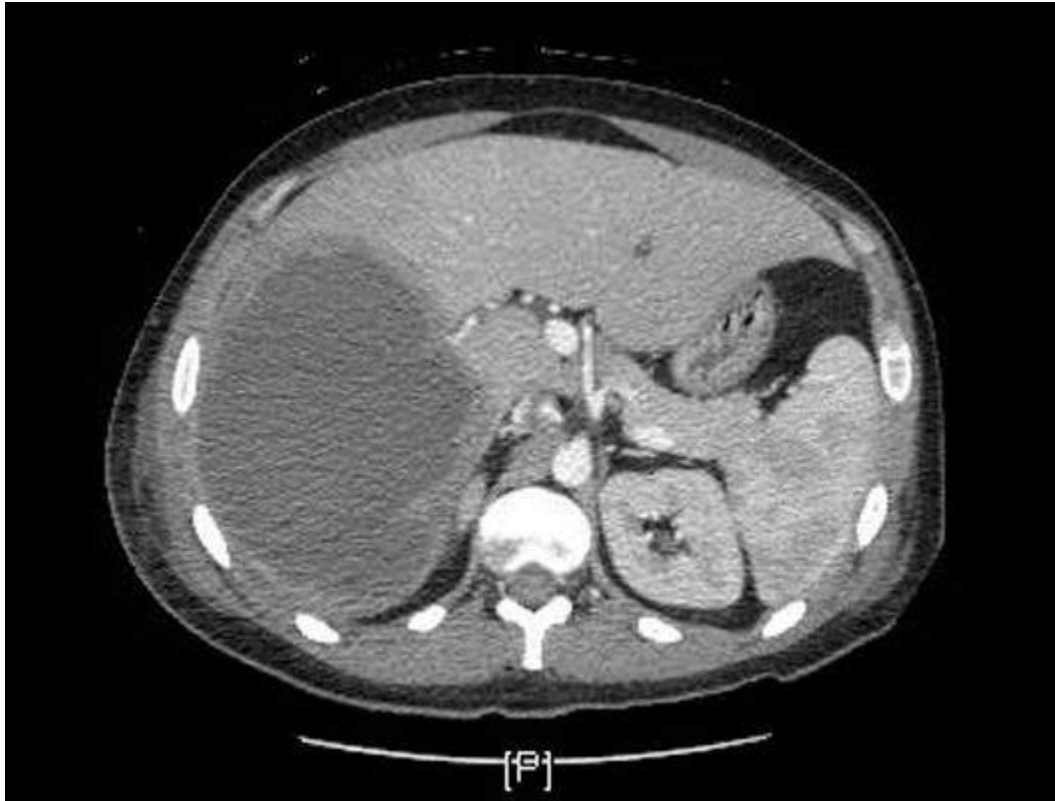
The subsequent CT reveals the lesion which was a large retrosternal goiter.



Imaging data – Case 7

Question:

This 25 year old man has recently returned from a 6 month trip backpacking around South Asia and presents with fevers, diarrhoea and vomiting and right upper quadrant pain. What is the differential diagnosis for the main finding on his CT abdomen?

**Answer:**

Bacterial infection, usually haematogenous spread via the portal vein from an intra-abdominal source.

Amoebic infection, classically *Entamoeba histolytica*.

Fungal infection, classically *Candida*.

Imaging data – Case 6**Question:**

This 76 year old man with a previous C4-6 fusion, fell off a stool whilst changing a light bulb. He had evidence of quadraparesis which appeared to be more marked in his upper limbs compared with lower limbs. Identify the key features on this T2 sagittal MRI, and how does this explain the clinical presentation?



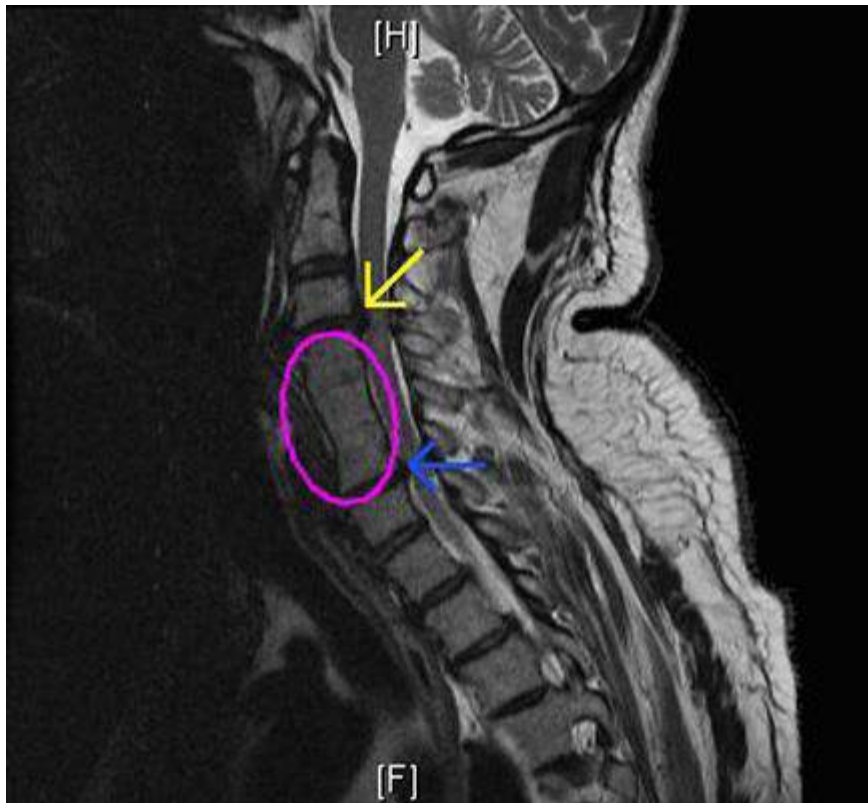
Answer:

Interbody fusion of C4-6 vertebrae inclusive (Pink ellipse).

C3/4 there is posterior disc protrusion (Yellow arrow).

C6/7 less marked posterior disc protrusion (Blue arrow).

The clinical features are consistent with a central cord syndrome, which occurs more frequently in the elderly with cervical spondylosis complicating a hyperextension injury.



Imaging data – Case 35

Question:

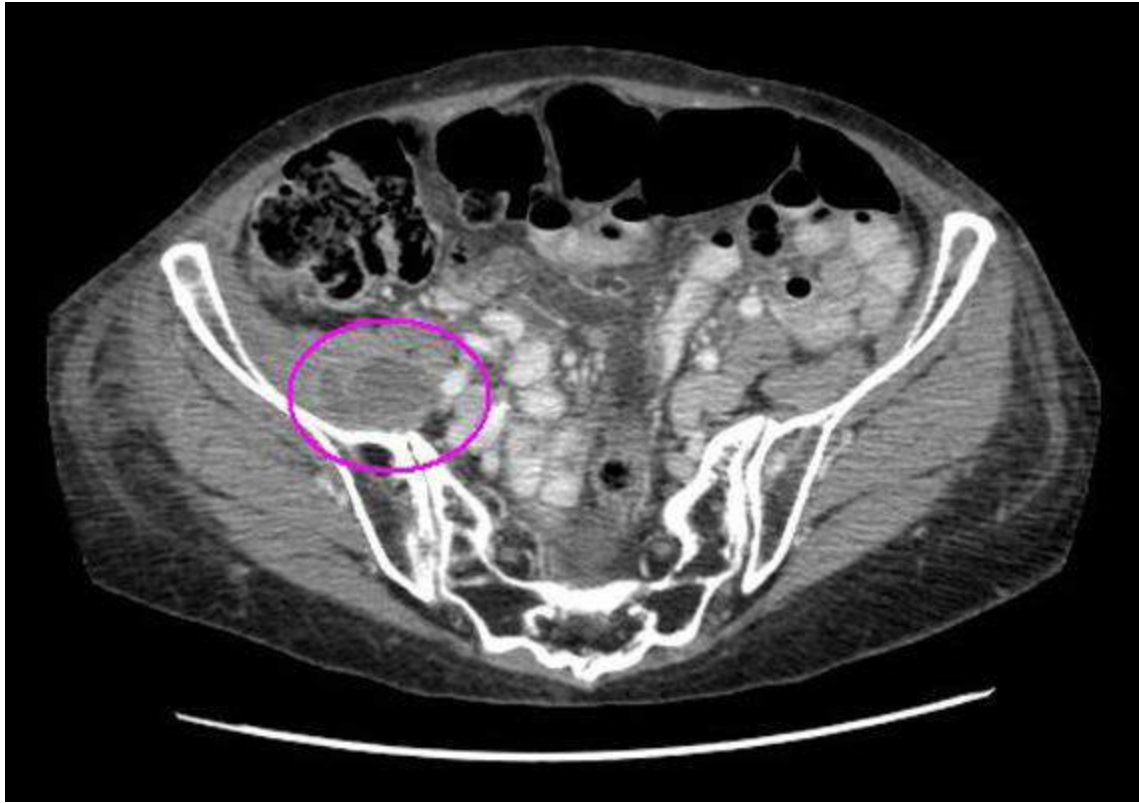
This elderly patient complained of severe right hip pain and deteriorated on the Orthopaedic ward with septic shock requiring intubation and ventilation. A CT of her abdomen, pelvis and right hip was performed with contrast. What is the likely cause of this clinical picture and what other investigations would you consider performing?



Answer:

There is a right iliopsoas muscle abscess.

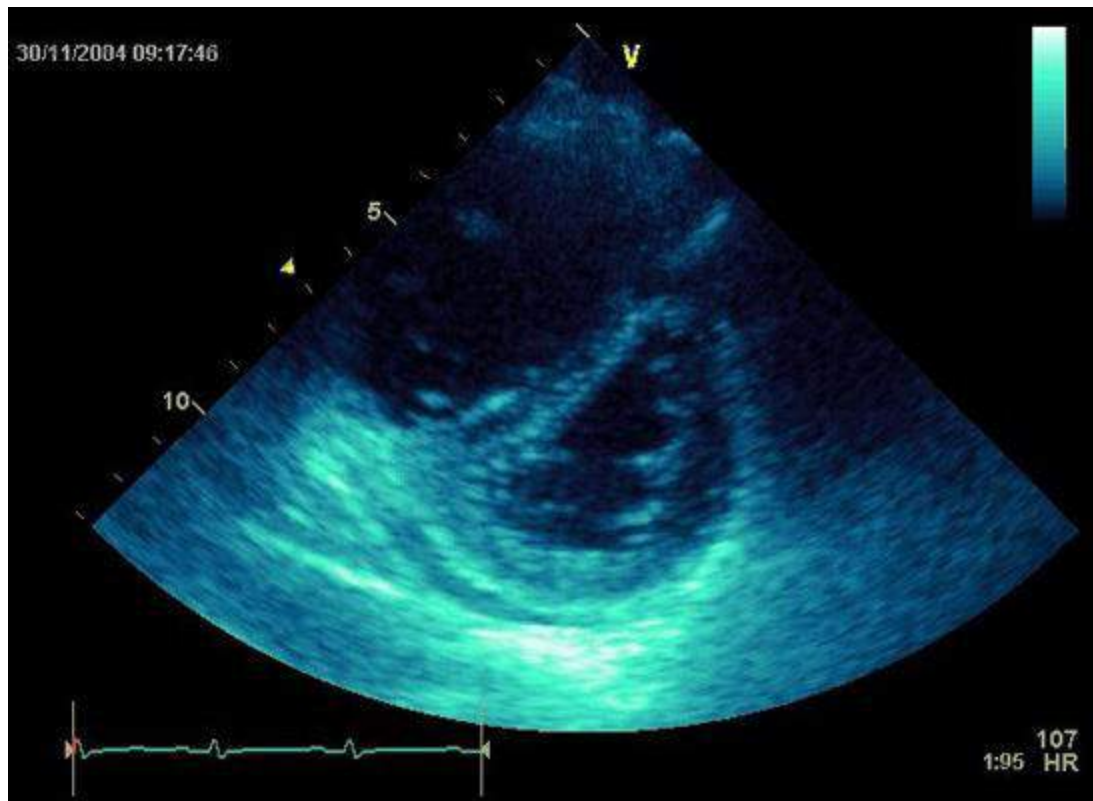
A transoesophageal echocardiogram and imaging of the spine (e.g. MRI) should be considered. A source of the infection should also be sought including cutaneous lesions and wounds and foreign material such as vascular access catheters and surgically implanted devices. (The most common infective cause is *Staphylococcus aureus*, which has a predilection for causing infection at multiple classical sites including the spine and heart valves.)



Imaging data – Case 37

Question:

A 43 year old lady, who has been mechanically ventilated in the ICU for the past three weeks because of Guillain-Barré syndrome, becomes suddenly hypotensive and tachycardic. Her SpO₂ falls to 78% and she becomes drowsy. A bedside transthoracic ECHO is performed and a captured image is displayed below. The sonographer informs you that the V_{TR} is 4.9 m/Sec and the estimated RAP is approximately 10mmHg.



- a) What pathology would you consider based upon the results of the transthoracic ECHO?
- b) How do the results influence your management of this patient?

Answer:

- a) Acute massive pulmonary embolism
- b) In this patient's context, emergency thrombolysis

Imaging data – Case 27

Question:

This patient has had a debridement procedure for dehiscence due to deep sternal wound infection complicating their cardiac surgery.

- a) What are the risk factors for sternal dehiscence?
- b) Your resident is also wondering about the lesions in both lower lung fields. What do you think they represent?



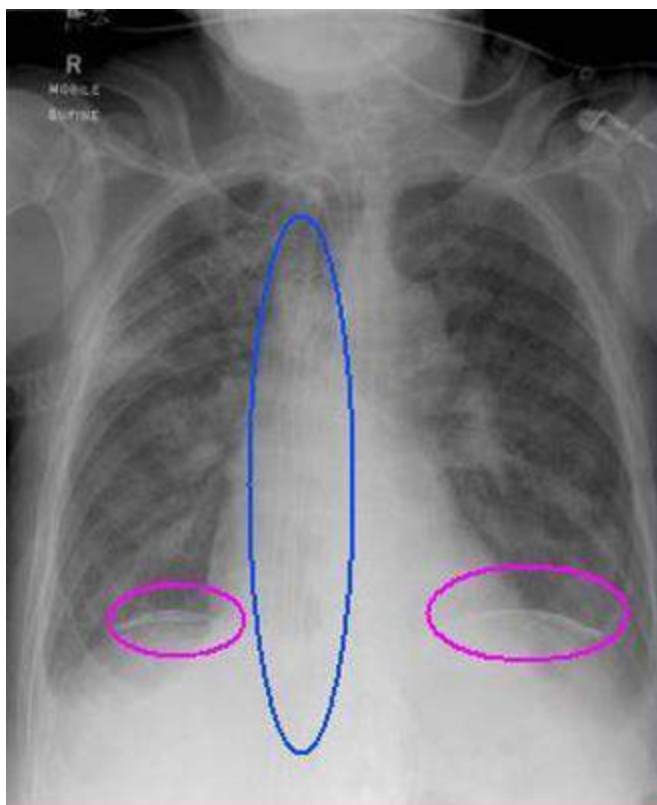
Answer:

a) Sternal dehiscence risk factors:

1. obesity
2. diabetes mellitus
3. immunosuppression
4. excessive coughing
5. internal mammary artery grafts (especially if bilateral)
6. prolonged surgery
7. massive bleeding
8. high dose vasopressors

(The radio-opaque lines within the blue ellipse are the packing material in the wound cavity and indicate that the sternotomy wound has not yet been fully closed.)

b) The bibasal lesions are pleural plaques and suggest prior asbestos exposure.



Imaging data – Case 11

Question:

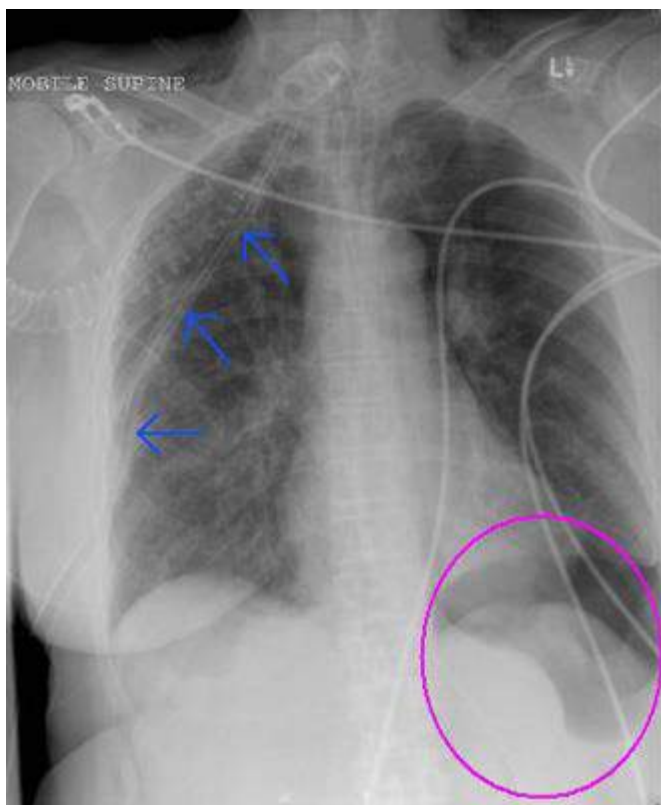
Why was this patient difficult to ventilate?



Answer:

There is a left sided anterior pneumothorax (Pink ellipse) as evidenced by hyperlucency over the hemidiaphragm. (It is anterior rather than posterior as it is a supine film and air rises .)

There is a right-sided chest drain (Blue arrows) suggesting that a pneumothorax has already been treated on the other side.



Imaging data – Case 13

Question:

What procedure has this patient had performed? What are the indications for this intervention?



Answer:

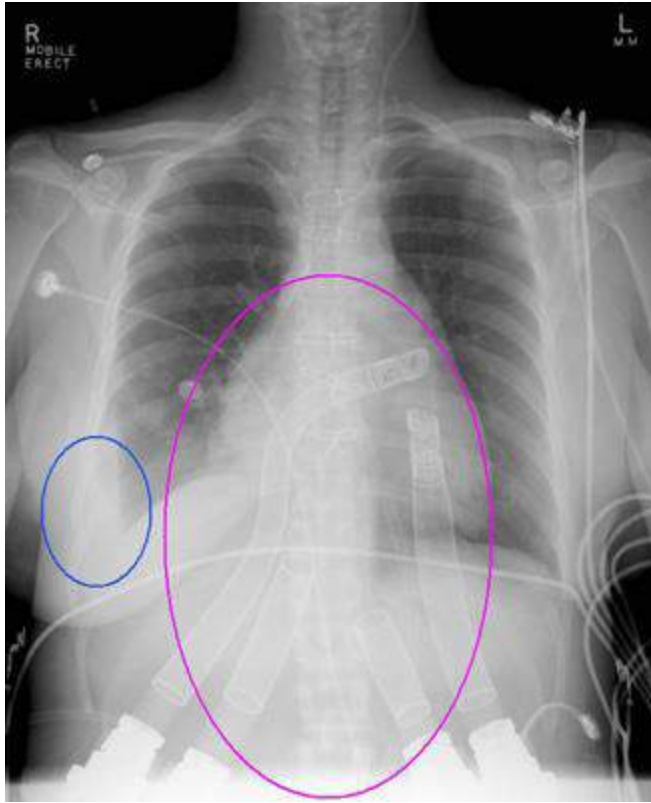
This is a BIVAD (biventricular assist device). Such devices are inserted into patients with severe heart failure most often as a bridge to transplantation.

Indications:

1. Bridge to recovery (e.g. viral myocarditis)
2. Destination therapy in patients unsuitable for a heart transplant (e.g. older patients)

Description

There are four striking tubular opacities ending over the heart (Pink ellipse). There are a number of different models with different appearances of which this is one variant, made by Thoratec™. There is also a right base effusion (Blue ellipse).



Imaging data – Case 23

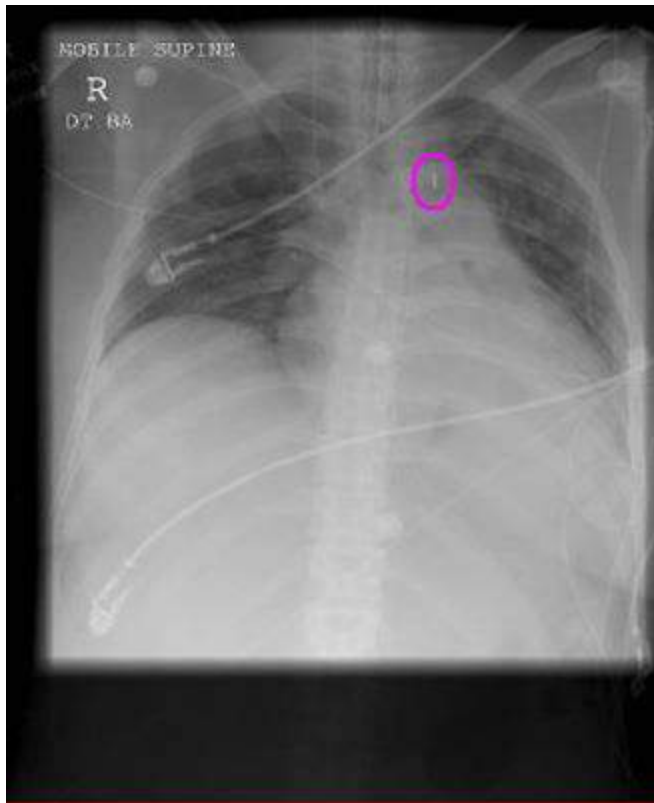
Question:

This patient had cardiac surgery earlier today. Are you happy with the intra-aortic balloon pump position and what phase of the cardiac cycle was the film taken in?



Answer:

The balloon pump tip has a radio-opaque marker that is located above the first rib anteriorly. Ideally it would be located just above the left main bronchus in the second or third intercostal space anteriorly. If it is too high it may occlude the left subclavian artery causing limb ischaemia. The balloon is not open in this film suggesting the cardiac cycle was in systole at the time the CXR was taken.



Imaging data – Case 29

Question:

This 35 year old, previously well patient presented with haemoptysis and respiratory failure. Acute renal failure rapidly followed. List 4 possible causes for this clinical picture.



Answer:

1. Goodpasture's disease
2. Wegener's granulomatosis
3. Systemic Lupus Erythematosus including Catastrophic Antiphospholipid Syndrome
4. Microscopic Polyarteritis Nodosa

Description

Bilateral diffuse airspace opacification, involving all 4 lung quadrants. There are denser opacities in the right upper and lower zones, which may represent consolidation or increased amounts of alveolar fluid.

There is an endotracheal tube in place, that may need to be advanced a further 1 – 2 cm.

There is a right internal jugular central venous catheter, which, allowing for the rotation of the film, looks to be appropriately positioned.

ECG leads and ventilator tubing are visible on this mobile, supine film.

Imaging data – Case 32

Question:

This patient was admitted with severe community acquired pneumonia. Which lobe(s) are affected?



Answer:

Right middle (the right heart border is obscured) and lower lobes (the hemidiaphragm is obscured).

Imaging data – Case 31

Question:

This patient had cardiac surgery three days ago. What operation have they had and what complication is holding up their discharge from ICU?

REVEAL ALL ANSWERS

Monitoring data – Case 13

Question:

The following patient was weaning from ventilation using a gradual reduction with a Pressure Support Ventilation (ASB) mode and a reducing level of support above PEEP. The nurse is worried that the flow trigger sensitivity has been set unusually high and wants to reduce it. Do you agree? What are the problems associated with setting the trigger sensitivity too high and too low?



Answer:

Yes - common sensitivity setting is 3L/min

Value set too high (Low sensitivity)

- The patient must work much harder to create the necessary flow to trigger a breath, the absence of which may result in erroneous triggering of mandatory apnoea ventilation

Value set too low (High sensitivity)

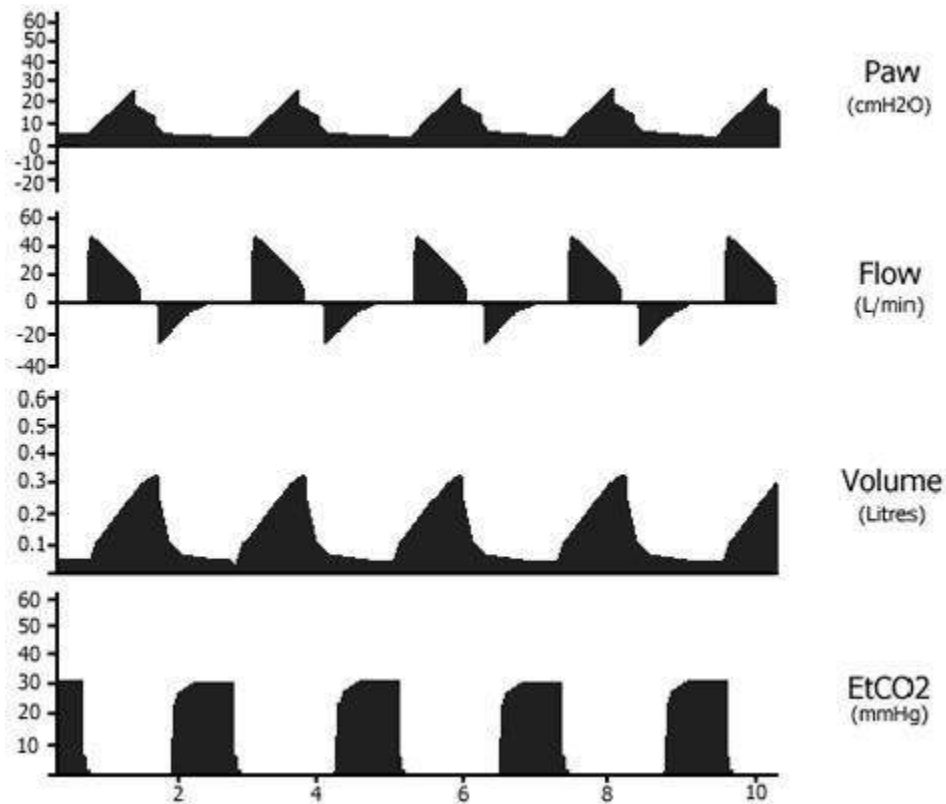
- Auto-triggering

Monitoring data – Case 10

Question:

A 25 year old gentleman has been mechanically ventilated for 5 days in the ICU following admission for polytrauma that included a traumatic brain injury, multiple stab wounds to the chest and a left ulnar shaft fracture. There is a

massive air leak from the chest drain. The ventilator display shows the following waveforms, with an FiO_2 of 0.7. Outline the principles of management of this condition and list 4 therapeutic options.



Answer:

Principles:

- minimise the flow across the fistula by reducing the transpleural pressure gradient to as low as is practical and safe
- extubate as soon as practical

Therapeutic options

1. Ventilation strategy - low V_t , slow rate, short inspiratory time, minimum PEEP to maintain oxygenation
2. Isolated lung ventilation – double lumen ETT, bronchial blocker

3. Surgical repair

4. Positioning – good lung up may reduce the fistula leak

(Additionally, regular airway suctioning and use of bronchodilators minimises expiratory resistance, need to maintain enough PEEP and negative suction on the ICC to prevent lobar atelectasis while avoiding an excessive transpleural gradient, nutritional support is important to assist healing and high frequency ventilation is an option. Note however, that while these strategies can improve oxygenation and reduce flow across the fistula, none have been shown to improve the overall patient outcome.)

Monitoring data – Case 17

Question:

A 36-year-old male experienced an out of hospital cardiac arrest requiring 30 minutes of CPR after injecting amphetamines. The initial rhythm was Ventricular Fibrillation. He was initially cooled for 24 hours to 34.5°C. By day 6 he still had not woken up and had sluggishly reactive pupils. His GCS was 3. A CT brain scan was initially normal and an MRI on day 5 demonstrated multiple areas of probable infarction consistent with a hypoxic-ischaemic brain injury. He had somatosensory evoked potentials performed to assist prognostication. How would you interpret the result?

		RIGHT MEDIAN		LEFT MEDIAN	
		Latency (msec)	Amplitude (μ V)	Latency (msec)	Amplitude (μ V)
Brachial	N9 :	11.1	3.3	10.8	2.8
Cervical	N11 :				
	N13 :	14.7	1.3	14.6	1.3
	N14 :	14.7	1.3	14.6	1.3
Cortical	N20 :	-	-	-	-
Arm Length (cm) :		-			

Comment: The potentials at Erb's point and the cervical spine are within normal limits. The scalp potentials are absent bilaterally.

Answer:

The results are consistent with reduced cerebral impulse conduction, consistent with a severe hypoxic-ischaemic brain injury. The prognosis is poor for a functional recovery.

Monitoring data – Case 20

Question:

This patient has just had an arterial blood gas performed that revealed a paCO_2 of 50mmHg (6.7 kPa). List 4 possible causes of this scenario?



EtCO_2 33mmHg = 4.4kPa

Answer:

1. Pulmonary embolism
2. Low cardiac output state
3. Emphysema
4. Severe alveolar gas trapping, e.g. severe asthma

Monitoring data – Case 2

Question:

A 73 year old patient has returned from an on-pump three vessel CABG 2 hours ago. She has remained hypotensive since her return. She has a background of type 2 diabetes mellitus, hypertension and mild emphysema. She has received 2 litres of colloid since her return and is on 0.25mcg/kg/min of noradrenalin (norepinephrine). You are shown her latest PA catheter data. What aspects would you check on assessing the patient for the cause of her persistent hypotension and how would you respond to each?

HR 115 bpm	C.O. 3.2 L/min
MAP 52 mmHg	C.I. 2.0 L/min/m ²
CVP 5 mmHg	SVR 1880 dyne-s/cm ⁵
RV pres 16/2 mmHg	SVRI 2805dyne-s/cm ⁵ /m ²
PA pres 16/5mmHg	PVR 20-100dyne-s/cm ⁵
mPAP 8 mmHg	PVRI 180dyne-s/cm ⁵ /m ²
PAoP 4 mmHg	SV 31 ml

Answer:

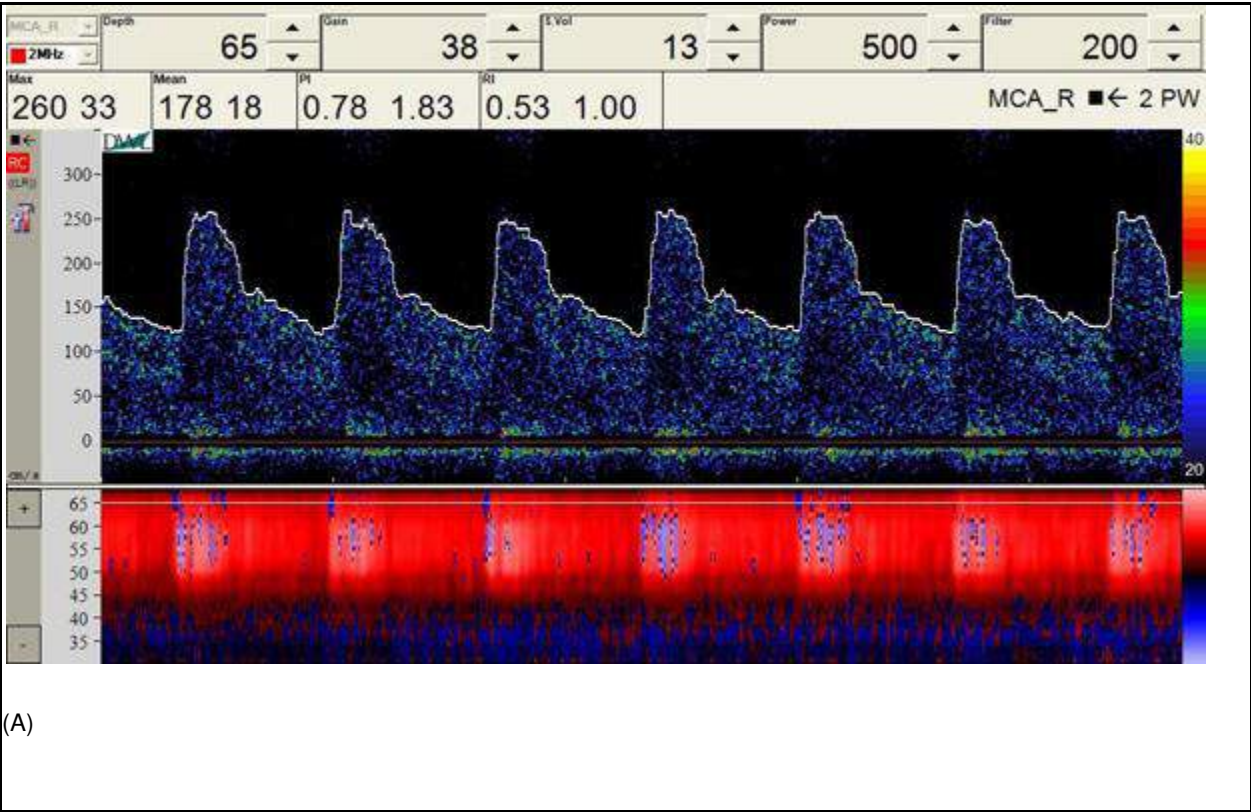
- Check anaesthetic record for mismatch of volumes lost and replaced.
- Physical examination for evidence of peripheral hypoperfusion
- Mediastinal drain output rate – If > 200ml/hr then advocate for return to theatre if no significant coagulopathy to be corrected.
- Identify and correct any coagulopathy; e.g.
 - aPTT (Heparin for CPB) – Protamine
 - low platelets (CPB mediated destruction) – pooled platelets
 - hypothermia (CPB and cardioplegia) – passive and active warming
 - acidosis – identify and correct cause
 - use of aspirin or clopidogrel within 5 days of surgery – pooled platelets
 - significant uraemia due to ARF – dialysis.
- Check latest Hb trend for acute blood loss – Replace to > 7.0 g/dL (higher if ongoing bleeding or active ischaemic cardiac features) and differentiate surgical from coagulopathic bleeding.

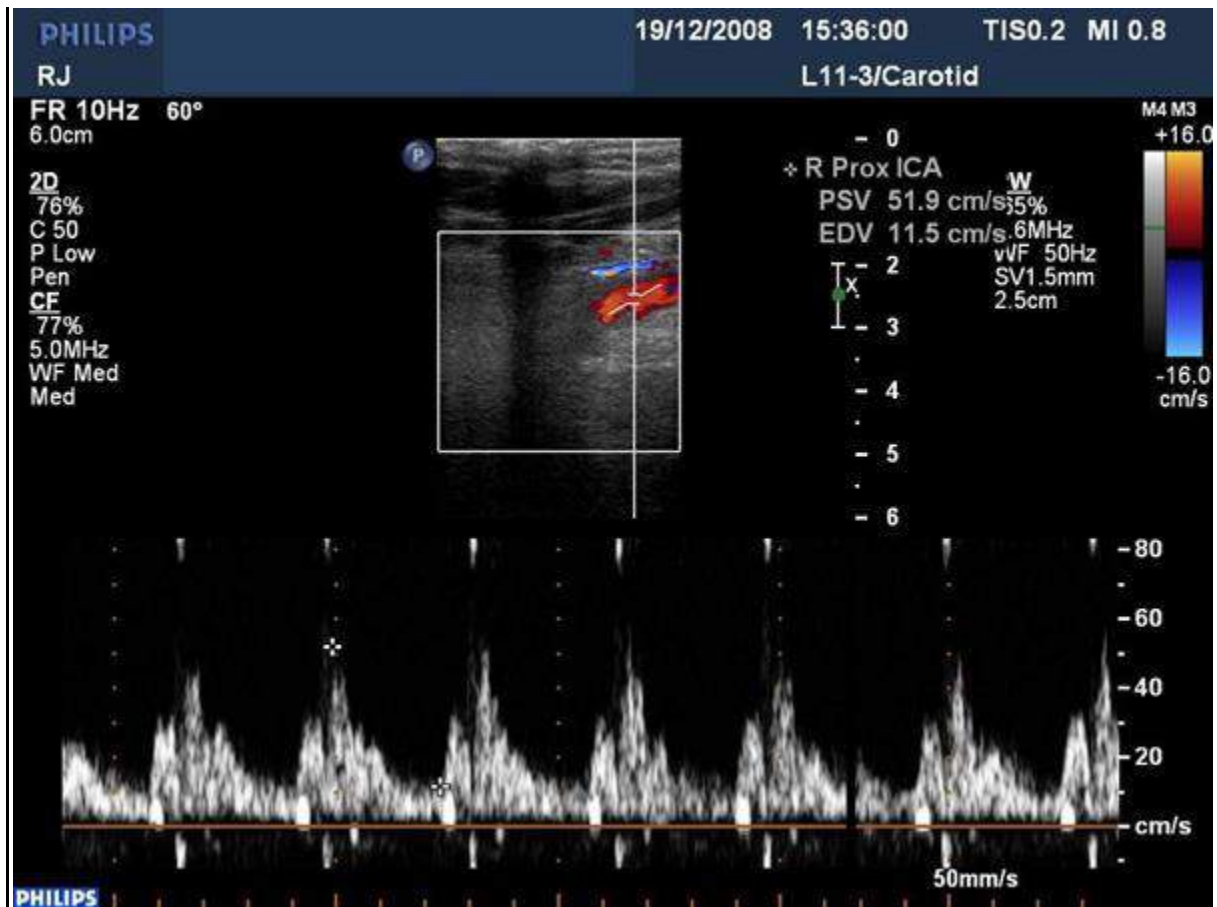
Monitoring data – Case 15

Question:

A 36 year old patient is day 5 of his admission to the ICU following a witnessed collapse. The CT brain showed a Fischer grade 3 subarachnoid haemorrhage. His level of consciousness deteriorated from withdrawing from a central

noxious stimulus, to extension to the same stimulus. His pupils remain equal and reactive to light. His EVD does not appear to have increased in its output rate. The following investigation is performed.





(B)

- What is this investigation?
- What does it demonstrate?
- List 3 management options.

Answer:

a) Image A = Transcranial Doppler study of the right MCA. Image B = Right internal carotid artery

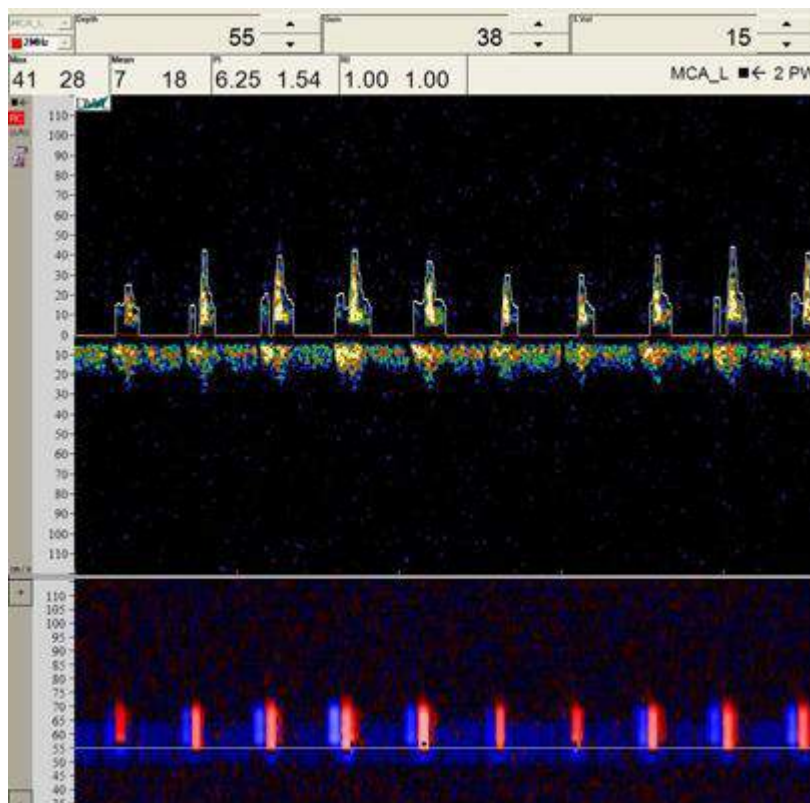
b) Moderate cerebral artery vasospasm in the right MCA with a Lindegard ratio of 5 ($260/52 \text{ cm.s}^{-1}$)

- c) 1. Ensure the patient is receiving nimodipine
2. Radiologically guided intra-arterial verapamil
3. Percutaneous angioplasty

Monitoring data – Case 16

Question:

A 22 year old female, who was admitted following a prolonged episode of acute severe asthma. The responding ambulance noted a weak carotid pulse, with no respiration. CPR was performed and she was intubated at the scene and given IM and IV adrenaline. She remained sinus tachycardia during transport. She was rapidly transported to the ICU for further care. Her neuromuscular blockade was ceased on day 2 and her sedation was ceased later that day. 2 days later she still has not had a motor response to a noxious stimulus and her pupils remain unreactive. A CT brain shows no abnormalities and an EEG is reported as demonstrating no evidence of seizure activity. A transcranial Doppler study is performed.



TCD report: M-mode demonstrates discontinuous brief blue/red signals at the same depth for both the right and left MCA at 55 and 70mm. The Doppler spectrum demonstrates high resistance flow.

How can the result of the TCD be used in her further management?

Answer:

The TCD result suggests that there is very limited MCA flow with a significant degree of proximal occlusion. Both the left and right MCA are affected at two separate distances, suggesting that this is a global process; in this context, global cerebral oedema, most likely due to hypoxic-ischaemic encephalopathy.

As there is flow demonstrated, albeit very limited, brain death cannot be diagnosed by this imaging modality. However, TCD is not an accepted definitive investigation for making this diagnosis and is instead often used to determine the optimal time to perform a 4-vessel angiogram with a reasonable chance of avoiding a residual flow, or a false positive or false negative result.

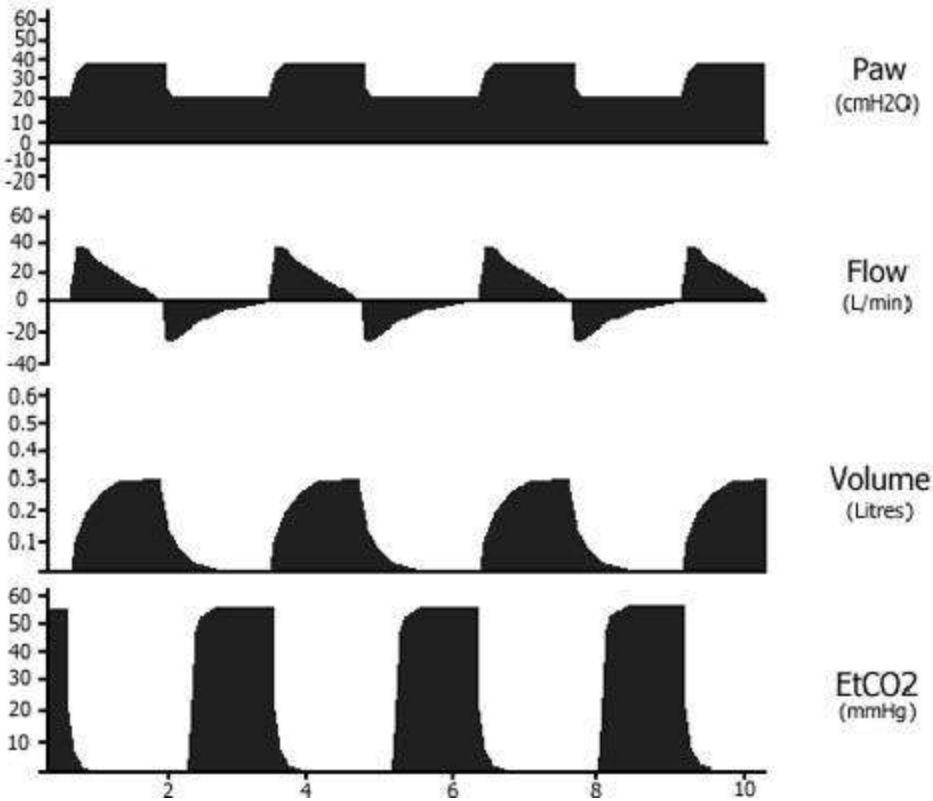
Otherwise, for now treatment would continue until such time as brain death is clinically or radiologically established, or a decision to withdraw curative treatment on the grounds of futility (some prefer the term "lack of therapeutic benefit") is made.

Monitoring data – Case 8

Question:

This patient is being ventilated with an FiO₂ of 0.9.

- a) What type of pulmonary deficit is suggested by the ventilator waveform displayed below?
- b) List 8 causes of this pattern of pulmonary deficit.



Answer:

a) Poor pulmonary compliance during PCV, with hypercapnoea, suggesting impaired gas exchange

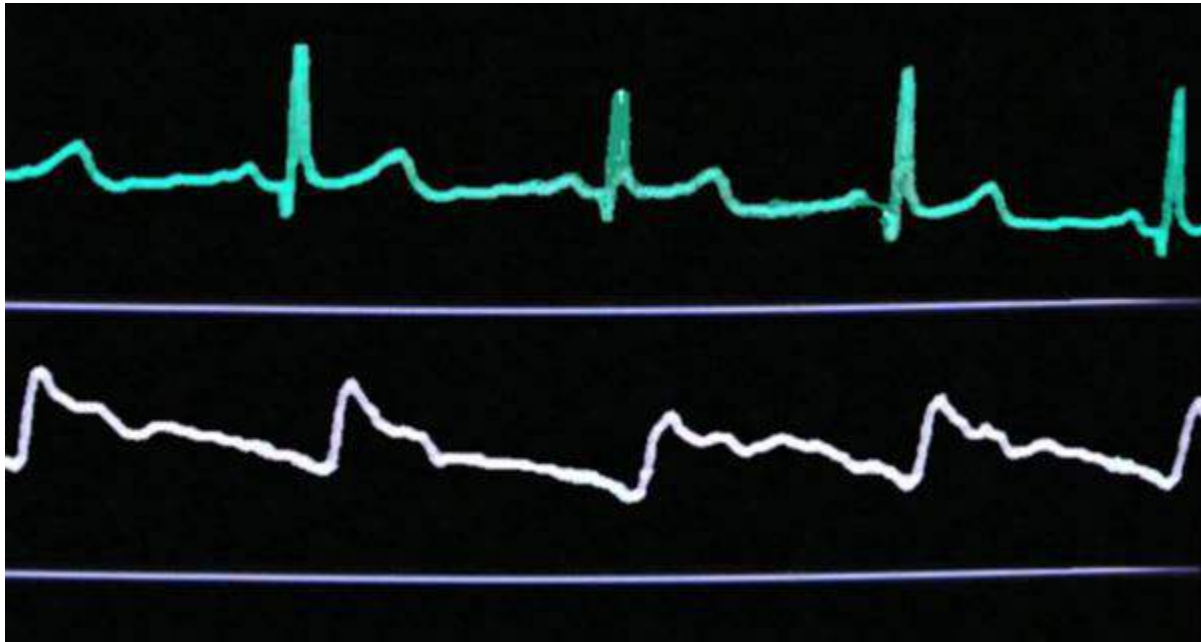
b) Causes of acute lung injury; e.g. ARDS:

- 1. Sepsis
- 2. Massive aspiration pneumonitis
- 3. Inhalation injury
- 4. Fat embolism
- 5. Amniotic fluid embolism
- 6. Pancreatitis induced acute lung injury
- 7. Major trauma
- 8. Massive blood transfusion (TRALI)

Monitoring data – Case 21

Question:

The white waveform shown is of the ICP waveform of a patient with a severe traumatic brain injury. The pressure at this time was 14mmHg. The aim of therapy was <20mmHg. Give 2 reasons why you think the reading is likely to be an accurate reflection of intracranial pressure.



Answer:

A normal non-damped waveform is seen with a clearly visible P1, P2 and P3. If intracranial compliance was poor a prominent P2 would be expected.

Monitoring data – Case 6

Question:

A 60 year old, known alcoholic patient has been admitted through the emergency department earlier today. He had been complaining of abdominal discomfort, increasing dyspnoea and intermittent fevers. He became hypotensive in the ED and received 2000mls of crystalloid and, following a lactate reading of 5mmol/L on a blood gas result, was commenced on noradrenaline at 0.08mcg/kg/min. He was subsequently intubated for invasive ventilation, with an FiO₂ of 0.5 and a PEEP of 10cmH₂O, due to increasing respiratory effort and falling oxygen saturation. Empiric antibiotics have been commenced. A LiDCO monitor is attached and the readings are as follows:

HR 104 bpm	SV 30 ml
MAP 53 mmHg	SVRI 2454 dyne-s/cm ⁵ /m ²

CVP 10 mmHg	SVV 24%
CI 1.4 L/min/m ²	

a) What intervention would you perform?

b) Following your intervention, his MAP still remains 58mmHg despite norpinephrine 0.4 µg/kg/min. He is peripherally cool and has an hourly urine of approximately 15mls/hour with a lactate that has fallen to 4.5mmol/L. His measured ScVO₂ is 60% on an FiO₂ of 0.5, with an SpO₂ of 97% and a Hb of 10.5g/dL. LiDCO readings show:

HR 88 bpm	SV 43 ml
MAP 60 mmHg	SVRI 2300 dyne-s/cm ⁵ /m ²
CVP 14 mmHg	SVV 8%
CI 1.6 L/min/m ²	

What intervention would you perform?

Answer:

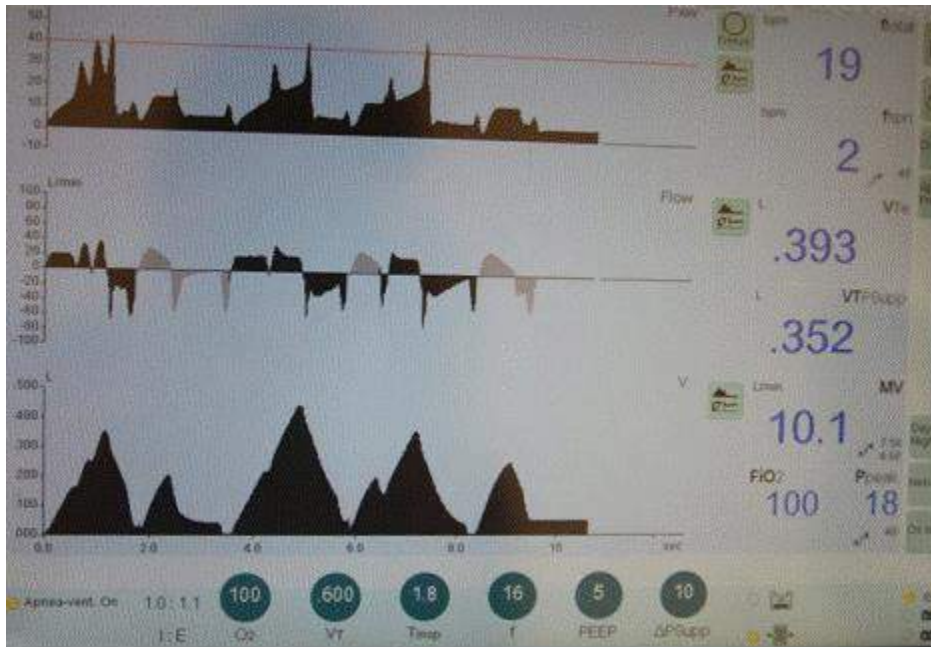
a) Give a 500ml fluid challenge

b) Commence dobutamine. The use of corticosteroid therapy in this setting remains controversial but could be considered.

Monitoring data – Case 14

Question:

A 25 year old gentleman has been admitted to your ICU following a severe traumatic head injury, for which an ICP monitor and EVD have been sited. After the first 72 hours his ICPs have settled, without needing any intervention beyond sedation and haemodynamic control. This morning his sedative infusions were decreased and the neurosurgeons are considering removing the EVD. Your registrar is seeking assistance as she is having difficulty with the patient's ventilation, which has been set in an SIMV Volume Control with Pressure Support mode. What do you think is the cause of this difficulty? What are the potential aetiologies and how will you manage the ventilation?



Answer:

Cause of ventilator difficulty = ventilator dyssynchrony

Potential aetiologies:

1) Ventilator settings

- Mandatory breath rate (f) set too high in a patient capable of spontaneous breaths
- Trigger sensitivity too low (Value set in excess of 3L/min)
- The I:E ratio of 1:1 may be poorly tolerated by a patient who is not deeply sedated +/- under neuromuscular blockade.

2) Patient agitation

- Cerebral agitation from TBI

- Emerging sepsis (e.g. ventilator associated pneumonia, ventriculitis)
- Drug withdrawal (unlikely to be due to withdrawal of the sedative agents, but may be unmasking an underlying illicit drug or alcohol withdrawal)
- Pain / discomfort

Management

- Change ventilator mode from volume control to pressure support, to allow spontaneous breathing. Ensure a sufficient level of pressure support is set to achieve adequate tidal volumes. Ensure adequate minute volume and monitor ICP, EtCO₂ and/or PaCO₂ closely as there is a risk that hypercapnoea will be poorly tolerated after a TBI.
- Reduce mandatory breath rate, if mandatory breaths are still deemed necessary.
- Lengthen I:E ratio from 1:1 to 1:1.5-2
- Confirm appropriate trigger sensitivity (e.g. if flow triggered, then 2 – 3 L/min)
- Treat reversible aetiologies – analgesia for pain, benzodiazepines for withdrawal, verbal reassurance, ensure appropriate ETT position, suctioning of excess secretions.
- If agitation persists despite appropriate management of reversible causes, consider other drugs for cerebral agitation (e.g. clonidine, dexmedetomidine).
- If weaning of the ventilator is not feasible, may need to re-sedate in order to gain control of ventilation.

Monitoring data – Case 18

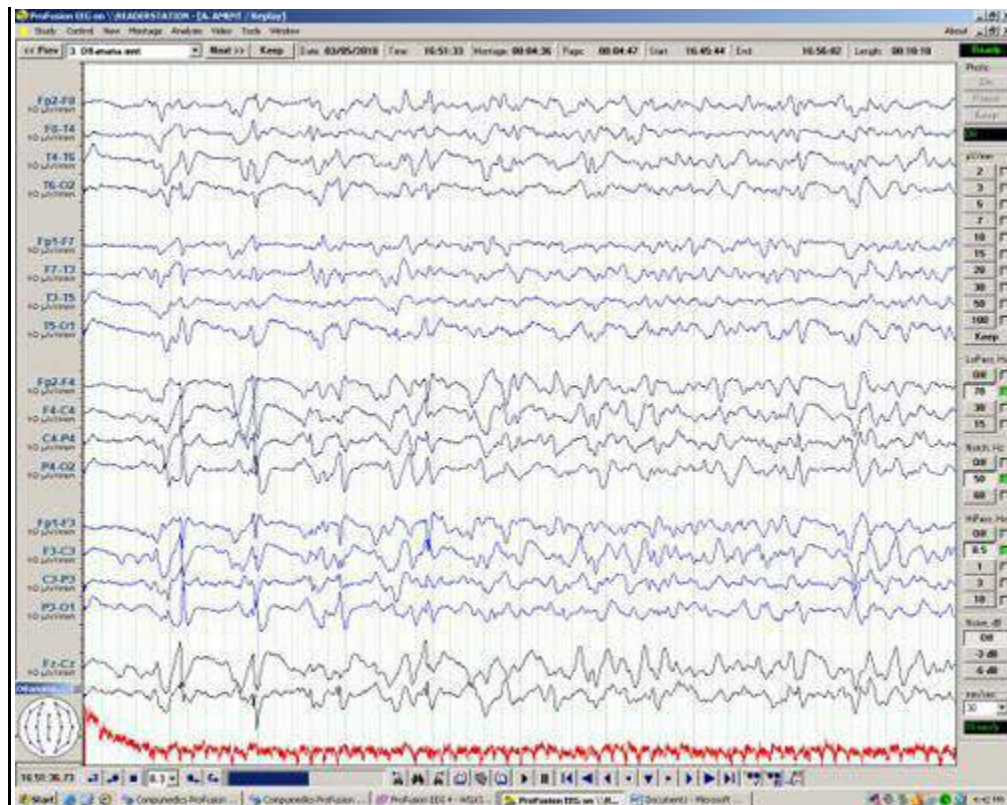
Question:

A 60-year-old woman with known chronic renal failure secondary to chronic glomerulonephritis, experienced a cardiac arrest 2 days ago due to hyperkalaemia. She was initially treated with therapeutic hypothermia and renal replacement therapy.

On day 5 she is not waking up and has been noted to have intermittent twitching of her face and limbs. An EEG was ordered and a sample of activity is shown both before (Image A) and after a bolus of intravenous midazolam (Image B). How would this influence your management?

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(B)

Answer:

Pre and post midazolam EEG suggest abolition of electrical seizure activity. Therefore, failure to wake may be a non-convulsive status epilepticus. I would attempt to control the seizures, in order to be better able to prognosticate. However, the use of antiseizure medications such as the benzodiazepines potentially introduce further uncertainty if she still does not wake. Additionally, status electrical activity post OHCA is associated with a universally poor outcome.

Monitoring data – Case 5

Question:

A 59 year old gentleman is in your ICU with 65% TBSA burns. He returns from theatre following an extensive debridement procedure. An oesophageal doppler has been inserted and the nurse has requested a review of the latest readings.

HR 96 bpm	FTc 262 mSec
CO 3.8 L/min	PV 58 cm/sec
SV 40 ml	

What intervention would you advise next?

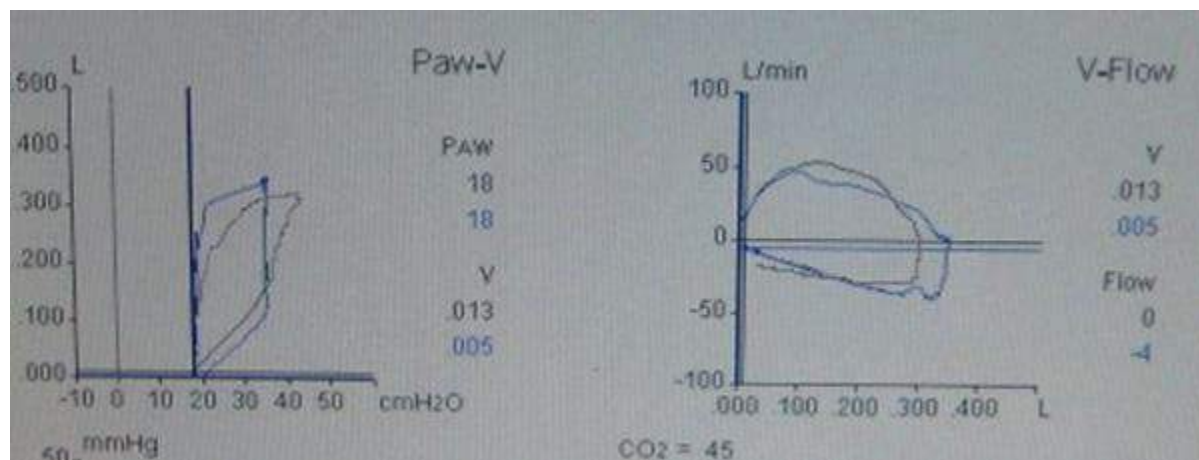
Answer:

Give a 500ml fluid challenge.

Monitoring data – Case 12

Question:

The "high pressure" alarm has been sounding on the ventilator of this patient, who is day 3 in your unit with ARDS due to H1N1 Influenza A. The ventilator loops are displayed below. What options are there for ameliorating this problem?



Answer:

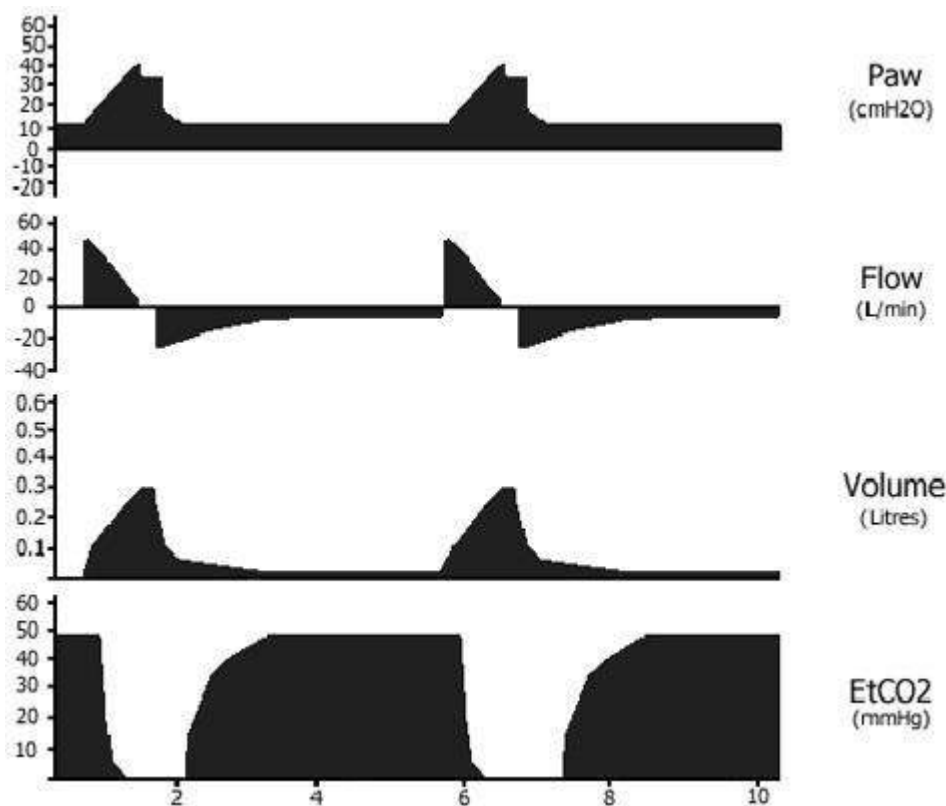
1. Provide a longer expiratory time; e.g. prolonged I:E ratio.
2. Decrease the respiratory rate (*f*)

3. Set ventilator PEEP to no more than 75 – 85% of the intrinsic PEEP (iPEEP), as measured by an expiratory hold on the pressure-time scalar.
4. Avoiding excessive tidal volume (V_t).
5. Use of bronchodilators if reversible bronchospasm is suspected.
6. Tracheal and ETT toilet.
7. Use the largest calibre ETT feasible.
8. Ensure adequate analgesia and anxiolysis.
9. Ensure the patient is adequately sedated and, if necessary has neuromuscular blockade, if it is suspected that the patient is breathing out forcefully against the ventilator. Alternatively, if the required ventilator support is minimal, and invasive ventilation is no longer required, extubate the patient.

Monitoring data – Case 9

Question:

List 6 therapies for the condition that is reflected in the following ventilator display of a 23 year old with acute respiratory failure.



Answer:

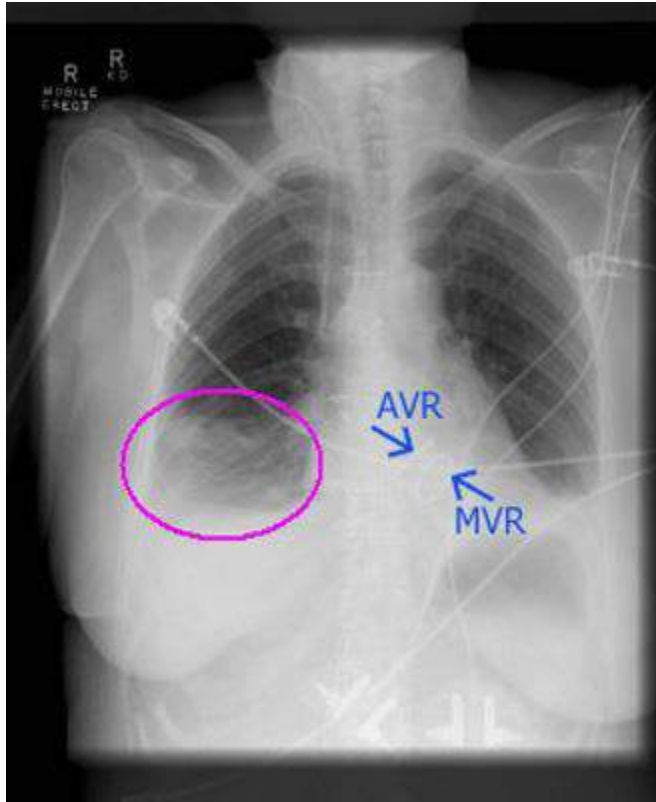
- Salbutamol, nebulised or IV infusion
- Adrenalin (Epinephrine) infusion
- IV hydrocortisone
- IV magnesium
- IV theophylline
- Heliox ventilation

(Additional therapies include nebulised ipratropium bromide, a ketamine infusion and the use of bronchodilating inhaled anaesthetic agents)

**Answer:**

There are two radio-opaque rings consistent with valve surgery . The oblique superiorly located valve with the slit-like appearance is consistent with an aortic valve replacement(AVR = aortic valve replacement). The lower, larger ring, that appears more laterally placed and is seen en-face, is a mitral valve ring (MVR = mitral valve replacement). There are several proposed methods for determining whether a prosthetic valve is likely to be aortic or mitral, based on position, shape, size and perceived direction of flow.

The patient has right lower lobe collapse-consolidation (Pink ellipse). The hemidiaphragm is obscured but the right heart border maintained. The horizontal fissure is shifted downwards.



Paediatric Case 14

Question:

A 10yr old child presents to the ED unresponsive and pulseless. The paramedics report that his mother is a known drug addict on the methadone program. You commence advanced life support and there is no response after three cycles. What is the actual dose of the drug below you would give and what sign on examination would help confirm the diagnosis?



Answer:

The dose of adrenaline is 10mcg/kg. To calculate weight use $(\text{age} + 4) \times 2$ which in this 10yr old would make them 28kg. This would be a dose of 2.8ml of 1:10000 adrenaline.

The most likely diagnosis is a drug overdose and if the pupils were pinpoint this would support the assumption of a methadone or opiate overdose.

Clinical case 26

Question:

The following drug may be used to induce prolonged therapeutic coma. Name three conditions where patients may benefit from this therapy and state the endpoints for the therapy in these scenarios. List 4 complications of this therapy.



Answer:

Thiopentone coma is a controversial therapy that may be used for patients with status epilepticus unresponsive to standard, less toxic therapies and patients with refractory raised intracranial pressure after traumatic brain injury. In these circumstances it is titrated to the lowest rate that controls seizures or pressure (e.g. less than 20mmHg). Some centres also use thiopentone coma to manage the neurological consequences of severe cerebral vasospasm by reducing cerebral metabolic demand (e.g. following a severe subarachnoid haemorrhage) with an end point of achieving burst suppression.

Potential complications include hypotension, immunosuppression with life-threatening nosocomial infections (especially VAP), hypokalaemia (with rebound hyperkalaemia if potassium is replaced to normal levels during coma), pupillary dilatation and loss of the light reflex with burst suppression that may be difficult to distinguish from brain death and delay its diagnosis.

Of note, thiopentone is soon to be withdrawn from the market and will no longer be produced by the manufacturer, as notified to the FDA on the 25th of January 2011.

Clinical case 32

Question:

A 65-year-old man received ifosfamide as part of his sarcoma chemotherapeutic regimen. The day after therapy he became progressively confused and drowsy and then had a generalised seizure. He was intubated and ventilated in the ICU and remains combative when propofol sedation is lightened. Could this scenario be associated with his chemotherapy? If so what is the most likely mechanism and what is the treatment?



Answer:

Ifosfamide is an alkylating agent used to treat a range of cancers including sarcoma, gynaecologic and testicular tumours as well as lymphomas.

Ifosfamide is classically associated with encephalopathy that may occur up to 2 days after it is administered and typically lasts for up to 3 days. There is no clear dose-response. Low serum albumin may be a risk factor. Clinical features range from dizziness, mood and behavioural changes to mutism, extrapyramidal signs, confusion, seizures and coma.

Ifosfamide encephalopathy may be related to the effects of chloroacetaldehyde, an active metabolite that crosses the blood brain barrier. Methylene blue appears to be an “antidote”. The precise mechanism remains unclear although it may reduce the formation of the metabolite and/or attenuate its effects. It is now used prophylactically.

Pelgrims J, De Vos F, Van den Brande J, Schrijvers D, Prove A, Vermorken J. Methylene blue in the treatment and prevention of ifosfamide-induced encephalopathy: report of 12 cases and a review of the literature. *Br J Cancer*. 2000; 82; 291-294.

Paediatric Case 26

Question:

A 5 year old girl, who is recovering from chicken pox, is brought into the emergency department having a convulsion. The paramedics have secured IV access and already given a dose of midazolam.

Her respiratory rate is 14, pulse 115 and capillary refill time normal. Glucose is normal.

What is the diagnosis?

What is your management plan?

Na 119
mmol/L

K 3.6
mmol/L

Cl 90
mmol/L

U 3.0
mmol/L

Gluc 9
mmol/L

Answer:

The diagnosis is SIADH. The management plan involves airway management if prolonged fitting and consideration of sodium replacement as other anti-seizure medications are unlikely to be effective until the sodium is >125.

Sodium can be replaced using 3% saline and the following calculation:

Sodium deficit (in ml saline) = $Wt \times 4 \times (\text{Na aiming for (usually 125)} - \text{current Na}) / \% \text{saline to be used for replacement}$.

$Wt = (5+4) \times 2 = 18\text{kg}$

Sodium deficit = $(18 \times 4) \times (125-119) / 3$

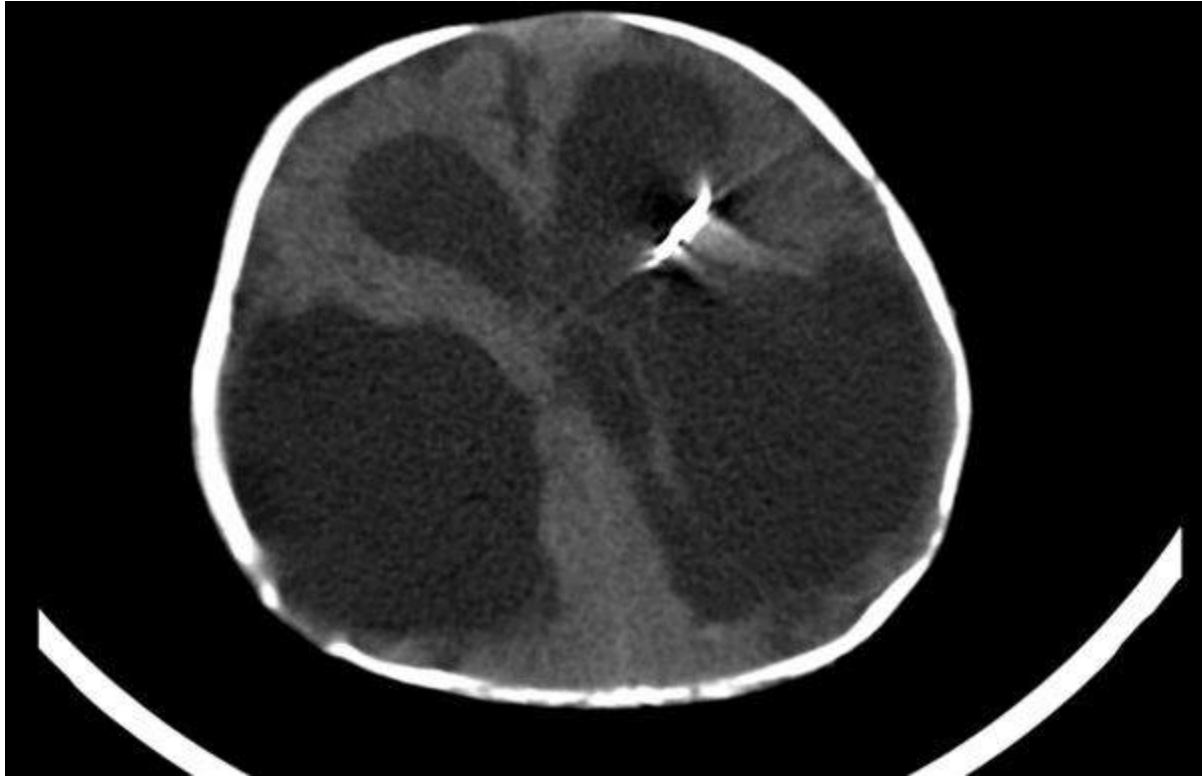
= 144mls of 3% saline

(Note: The biochemical pattern is also consistent with a diagnosis of cerebral salt wasting syndrome. However, it would be reasonable to suspect euvoemia given the normal capillary refill time, acknowledging the ongoing debate regarding its usefulness, which then makes SIADH more likely)

Paediatric Case 18

Question:

This 6 month old presented with developmental delay and failure to thrive. This is a progress slice of a CT head post procedure. What are the main features?



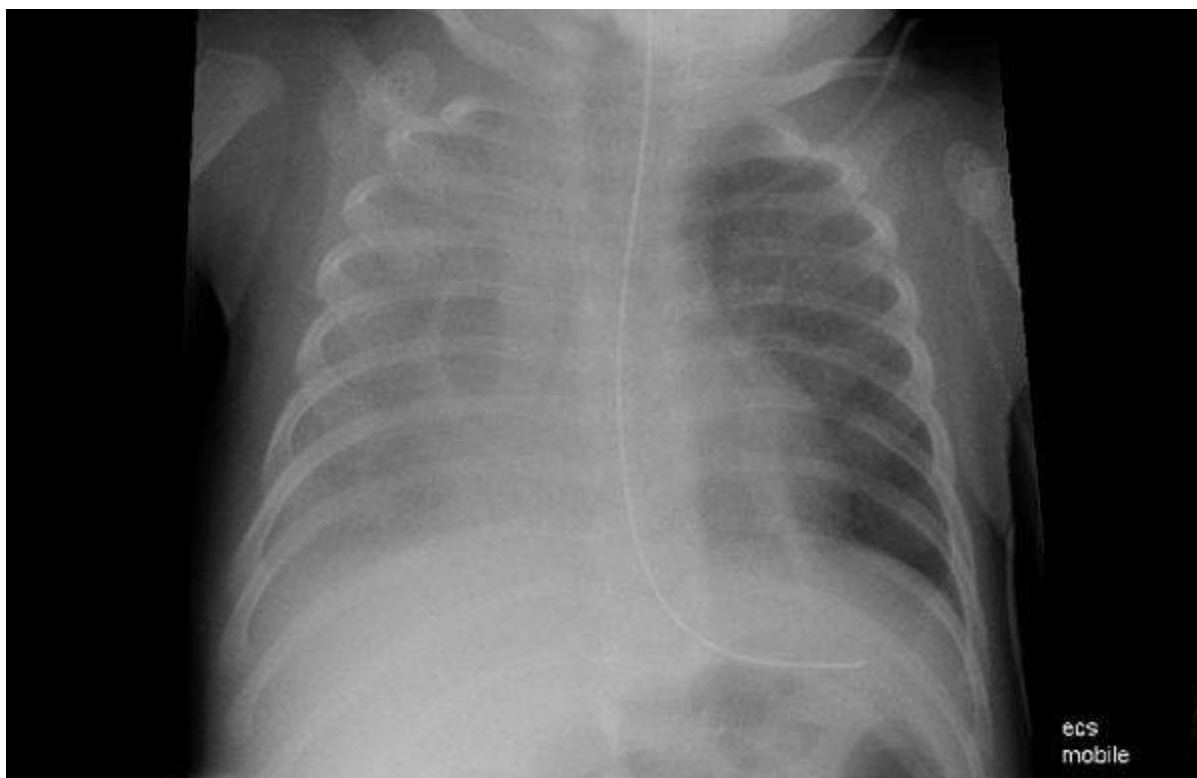
Answer:

The main features are gross hydrocephalus with evidence of an EVD in situ.

Paediatric Case 2

Question:

This 1 month old child presented with meningitis 7 days ago and has been ventilated in the PICU since admission. He has been increasingly difficult to oxygenate overnight and this is his CXR. Describe the main findings and suggest a diagnosis.



Answer:

Right sided consolidation with collapse suggesting infection. Intubated with NG tube in situ.

Clinical case 34

Question:

A 56-year-old man was admitted to ICU overnight, from the ward with respiratory failure. He was admitted to hospital 6 days ago with a diagnosis of community acquired pneumonia. His chest x-ray suggested bilateral pleural effusions were present and bilateral small bore drains have been inserted with an ultrasound guided Seldinger technique. The following specimens were obtained:



Right chest



Left chest

a) The bedside nurse has run a sample of each through the blood gas machine on the ICU and the following results are available:

	Blood gas 1	Blood gas 2
pH	7.603	6.372
Glucose	10.1	0.0
Lactate	2.3	22
Hb	0.6	0.1
paO ₂	162	37.6
paCO ₂	30.2	216

Which specimen do you think belongs with each result and why?

b) Only one of the specimens has reached the laboratory. The following results are available:

Serum biochemistry taken at time of drainage procedure:

Protein 37 g/L

LDH 158 U/L

Pleural fluid:

Protein 51g/L

LDH 7560 U/L

Which specimen do you think these results are from and why?

Answer:

a) Blood gas 1 is from the right chest and blood gas 2 from the left chest. The specimen from the right side looks haemoserous and non-turbid. The specimen from the left side looks purulent and the results suggest an empyema is present with an acidic pH, very high lactate and absent glucose.

b) The results are consistent with an exudate and therefore most likely from the left chest with an empyema. This is a well-described complication of pneumonia.

Pleural fluid: serum protein = $51/37 = 1.4$ (>0.5 defines an exudate by Light's criteria)

Pleural fluid: serum LDH = $7560/158 = 47.9$ (>0.6 defines an exudate by Light's criteria)

Paediatric Case 23

Question:

What is this? Explain how it is used?



BLUE				
WEIGHT	RESUSCITATION		RAPID SEQUENCE INTUBATION	
	PREMEDICATIONS		PREMEDICATIONS	
0.33 mg	Epinephrine (1:10,000)	0.21 mg (2.1 mL)	Atropine	0.42 mg
N/A	Epinephrine ET (1:1,000)	2.1 mg (2.1 mL)	Pan/Vecuronium	0.21 mg
N/A - 20kg	Atropine (0.1 mg/mL)	0.42 mg (4.2 mL)	(Defasciculating Agent)	32 mg
25 mg	Atropine ET (0.4 mg/mL)	0.6 mg (1.5 mL)	Lidocaine	63 mg
50 mg	Sodium Bicarbonate	21 mEq	Fentanyl	63 mg
5 mg	Lidocaine	20 mg	Etomidate	6.3 mg
50 mg	Lidocaine ET	40-60 mgs	Ketamine	42 mg
5 mg	Defibrillation		Midazolam	6.3 mg
33 mg	1st/2nd Dose (may repeat)	40J/80J	Propofol	63 mg
5 mg	Cardioversion		Succinylcholine (give atropine prior)	40 mg
50 mg	1st/2nd Dose	20J/40J	Pancuronium	4.2 mg
50 mg	Adenosine		Vacuronium	4.2 mg
30 mg	1st Dose	2.1 mg	Rocuronium	21 mg
3.3 mg	2nd Dose If Needed	4.2 mg	Pancuronium/Vacuronium	2.1 mg
3.3 mg	Amiodarone	105 mg	Lorazepam	1 mg
16 mg	Calcium Chloride	420 mg		
1.7 mg	Magnesium Sulfate	1050 mg		
0.8 mg				
18 KG	19 KG	20 KG	22 KG	

Answer:

This is a Broselow trolley. The child is measured using a Broselow tape and this then gives a weight. It is now well accepted in paediatrics that length-based weights are the most reliable for resuscitation. The system then uses a colour system to aid both equipment and medication doses for children between 3-36kg.

Paediatric Case 7

Question:

This neonate has known Fallots Tetralogy and is in PICU. What test are they having and what is the main finding you would expect to see in this condition? List the features of Fallots Tetralogy and discuss their operative management.

**Answer:**

The neonate is having an ECG with the main finding likely to be right ventricular hypertrophy.

The features of Fallots are:

- Ventricular septal defect

- Right ventricular hypertrophy
- Right ventricular outflow tract obstruction usually at the infundibulum, valve level or at both
- Overriding aorta

Surgery is done usually before 1 year of age and carries less than 5% perioperative mortality. The surgery endeavours to relieve the right ventricular outflow tract stenosis by careful [resection](#) of muscle +/- use of a patch to enlarge the RVOT and to repair the VSD with a [Gore-Tex](#) patch or a [homograft](#). Additional surgery may be done if needed depending on each child's cardiac anatomy.

Paediatric Case 11

Question:

What is the device below? Why is it useful in infants?



Answer:

This is a laryngoscope with a straight blade. These blades are used to directly lift the epiglottis, thereby uncovering the vocal folds. This is useful in infants in whom the epiglottis is proportionally large and usually long and stiff and therefore can cause problems by obscuring the cords. The main disadvantage is the potential for vagal stimulation causing laryngospasm or bradycardia.

Clinical case 19

Question:

A 39-year-old woman was admitted with a grade 2 sub-arachnoid haemorrhage. Her digital subtraction angiogram did not show an aneurysm. The neurosurgical team has asked you to commence nimodipine. What is the evidence for this therapy in this situation?

**Answer:**

Studies of oral nimodipine in aneurysmal sub-arachnoid haemorrhage suggest that compared to placebo it improves survival and reduces the rate of cerebral infarction due to vasospasm. There is also a suggestion, following a metanalysis, that a combination of 7-10 days of intravenous nimodipine followed by 2 weeks of oral nimodipine may reduce ischaemic complications. However, the evidence is moderate and it remains a controversial area.

Clinical case 12**Question:**

A 17-year-old, 35kg woman was admitted with severe electrolyte derangements, complicating long-standing anorexia nervosa. The following enteral nutrition is being delivered on day 2. List 3 methods for determining her caloric needs.

What would be your target-feeding rate for this patient using this feed? What complication would you be most worried about?



Answer:

Methods of estimating caloric needs include:

- Empiric calculation (e.g. 25-35kCal/kg/day)
- Use of predictive equations (e.g. Harris Benedict, Schofield)
- Indirect calorimetry

Using an empiric calculation the target rate would be

(30kCal x 35kg = 1500kCal; using 1kCal/ml feed pictured this would mean approximately 40ml/hr)

This patient is at high risk of developing refeeding syndrome. Frequent PO_4^{3-} measurement will be required for early detection of hypophosphataemia.

Clinical case 33

Question:

A 26 year old lady is brought to the emergency department with bradycardia, hypotension and a decreased level of consciousness. An empty packet of metoprolol was found near her, with a label on it that indicated it had been dispensed yesterday. An adrenaline bolus is given with no effect and she is intubated. List 3 modes of therapy for her suspected β -blocker toxicity, other than the one shown in the picture. Outline the proposed mechanism for the therapy shown in the picture.



Answer:

Therapeutic options

1. Adrenalin infusion
2. IV Glucagon
3. Temporary pacing, transcutaneous or transvenous

Intralipid is thought to act as a lipid sink, reducing the bioavailability of lipid soluble agents and thereby reducing their toxic effects in overdose. It was originally introduced in anaesthesia for the reversal of local anaesthetic induced cardiotoxicity, but its use has been extended to other lipid soluble drugs. While few RCTs have been conducted outside of local anaesthetic toxicity animal studies, registries of case reports have been set up in several countries to document the use of intralipid rescue, with all of the caveats that this entails. The optimal dose has not yet been established, though a bolus of 1.5ml/kg 20% intralipid with a subsequent infusion at 0.25ml/kg/min, to a total maximum of 8ml/kg has been proposed by Dr. Guy Weinberg, who has performed the majority of the animal trials and runs www.lipidrescue.org

Picard J, Meek T. Lipid emulsion to treat overdose of local anaesthetic: the gift of the glob (editorial). *Anaesthesia* 2006;61:107-9

Weinberg GL, Ripper R, Feinstein DL, Hoffman W. Lipid emulsion infusion rescues dogs from bupivacaine-induced cardiac toxicity. *Reg Anesth Pain Med*. 2003; 28:198-202.

Clinical case 23

Question:

The following signs were observed during clinical bedside case examinations. What is the likely significance of noting these two findings?



Answer:

“NO ECM” is short for “No External Cardiac Massage” and usually suggests that the patient has an open sternum, usually as a result of complicated cardiac surgery where bleeding and/or severe right ventricular dysfunction were problematic.

“NO BP taking in this arm” suggests that the patient has either had axillary node clearance (e.g. previous breast cancer surgery) or has an arteriovenous fistula and is a chronic dialysis patient. In this case there is a raised protrusion that looks like a vascular dilatation consistent with a fistula.

(Signs such as these must not be missed as they are important clues to underlying acute and chronic problems and pathologies.)

Paediatric Case 24

Question:

A 2 year old boy presents to ED with a 6 day history of gastroenteritis. He has a respiratory rate of 35, pulse of 145bpm, and an initial blood pressure of 90 systolic. A capillary refill time done centrally on his sternum is 4 seconds. On further examination and history from his mother he has been asking for drinks but continues to vomit and his eyes look a bit sunken. On examination you find that he has reduced skin turgor.

- Is this boy shocked and what would your management be?
- What is his fluid deficit?
- How would you calculate his maintenance fluid requirements?

Answer:

- Shock is a reflection of intravascular depletion whereas dehydration is related to total body fluid loss. Dehydration normally occurs slowly and the intravascular volume is normally maintained, however it can be associated with shock.

In this child there is evidence of shock with increased capillary refill time and tachycardia. A fluid bolus would be appropriate treatment.

Weight = (age + 4) x 2 = 12kg, so the fluid bolus would be 20 x 12 = 240mls.

- Fluid deficit is related to the % dehydration which is based on clinical examination. The most objective sign is drop in weight but it is unusual to have a pre-sickness weight available. In this child with a dry mouth and thirst associated with sunken eyes and reduced skin turgor the percentage dehydration is at least moderate or 10%.

The deficit is calculated from % dehydration x weight x 10 = total fluid deficit

In this 12kg child = 10 x 10 x 10 = 1000ml. This fluid is added to the maintenance calculated and is not given as a bolus but is generally given over 24hrs depending on the serum electrolytes.

- Maintenance fluid should be isotonic (0.9% normal saline) to avoid iatrogenic hyponatraemia. is calculated using the 4,2,1 rule or 100/50/20mls/kg total then divided into 24. In a 12kg child this equates to depending on rule used:

First 10kg = 4ml/kg/hr = 40mls + (2mls/kg/hr) = 44mls/hr

Or first 10kg = 1000mls + (50 x 2) = 1100/24 = 45mls/hr

DATA INTERPERTATION

Microbiology - Important definitions

- **Systemic Inflammatory Response Syndrome (SIRS)**
- The systemic inflammatory response to a variety of severe clinical insults manifested by two or more of:
 - Temperature $>38^{\circ}\text{C}$ or $<36^{\circ}\text{C}$
 - Heart rate >90 beats per minute
 - Respiratory rate >20 breaths per minute or $\text{PaCO}_2 <32\text{mmHg}$ (4kPa)
 - WCC >12 or $<4 \times 10^9/\text{mm}^3$ or $>10\%$ immature band forms
- **Sepsis**
- SIRS secondary to infection
- **Severe sepsis**
- Sepsis associated with organ dysfunction, hypoperfusion or hypotension including lactic acidosis, oliguria or altered mental state
- **Septic shock**
- Severe sepsis with hypotension (systolic blood pressure $<90\text{mmHg}$ or a decrease of $>40\text{mmHg}$ from baseline) despite adequate fluid resuscitation
- **Multiple Organ Dysfunction Syndrome (MODS)**
- Presence of altered organ function in an acutely ill patient such that homeostasis cannot be maintained without intervention
- **Acute Respiratory Distress Syndrome (ARDS)**
- Acute onset of impaired respiratory function with a $\text{PaO}_2/\text{FiO}_2 <200\text{mmHg}$ (27kPa), bilateral infiltrates on chest x-ray consistent with pulmonary oedema and a pulmonary artery occlusion pressure $<18\text{mmHg}$ or without clinical evidence of increased left atrial pressure
- In acute lung injury the criteria are the same except the $\text{PaO}_2/\text{FiO}_2$ ratio is $<300\text{mmHg}$ (40kPa)

- **Nosocomial pneumonia**
- Nosocomial pneumonia = pneumonia that is not incubating at the time of admission and develops after more than 48 hours of hospitalisation

- **Ventilator associated pneumonia**
- Ventilator associated pneumonia = nosocomial pneumonia occurring in a mechanically ventilated patient

- Clinical diagnosis:
- At least two of temperature $>38^{\circ}\text{C}$, WCC $>12 \times 10^9$, purulent tracheal secretions with new or progressive chest x-ray infiltrates
- Microbiological criteria including the utility of endotracheal aspirates and blinded invasive sampling remain controversial

E.g. Bronchoalveolar lavage specimen with $\geq 10^4$ cfu/ml or Protected brush specimen with $\geq 10^3$ cfu/ml

- **Central venous line infection**
- Colonised catheter = growth >15 cfu or $\geq 10^3$ cfu/ml from a catheter segment without clinical features of infection
- Exit-site catheter infection = presence of positive quantitative catheter culture in the presence of symptoms of local infection, in the absence of other foci
- Catheter-related bloodstream infection = isolation of the same organism from the catheter segment and a peripheral blood culture in a patient with features of infection not attributable to another focus OR defervescence of infection after removal of a catheter suspected of being infected

- **Invasive candidiasis**
- Highly likely if:
- Cultured from blood (especially if in two cultures collected at different times)
- Culture from a sterile site (e.g. CSF, peritoneum, endophthalmitis)
- Suggestive if:
- Cultured from tissue or burn wound biopsy
- Culture from two non-contiguous sites
- Identified spp. not a commensal

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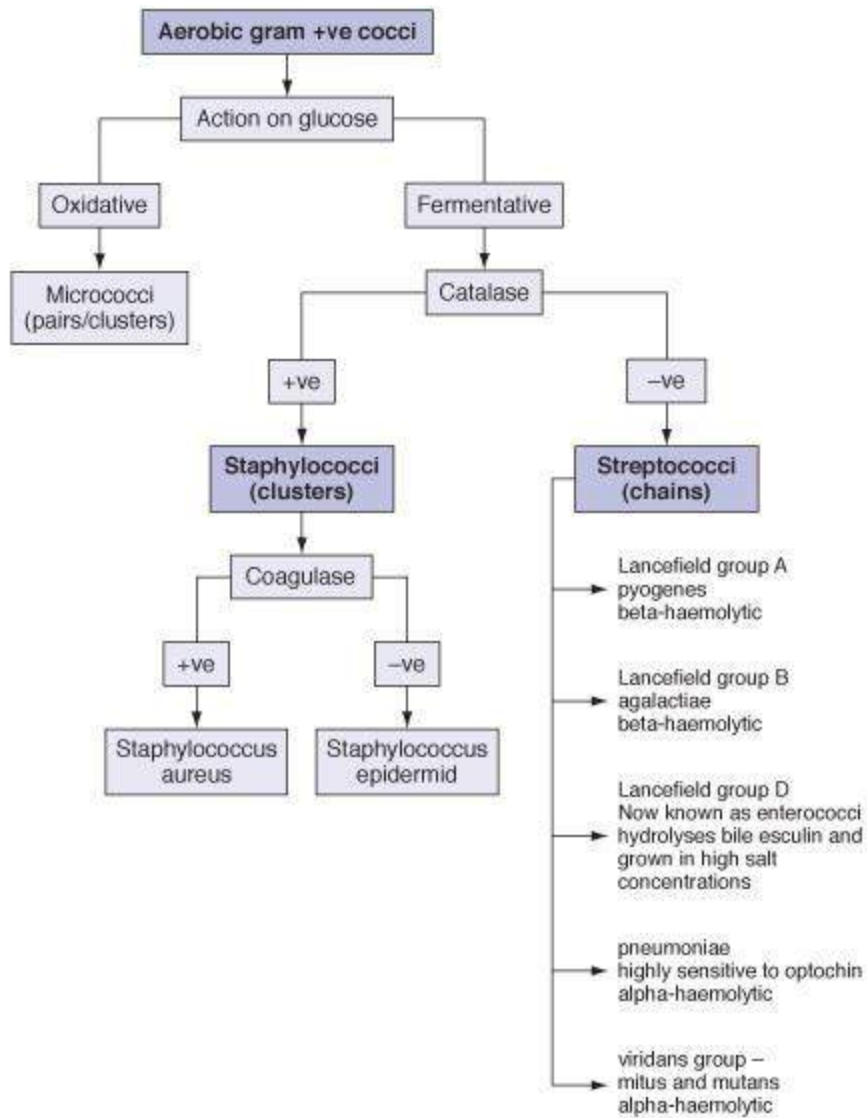
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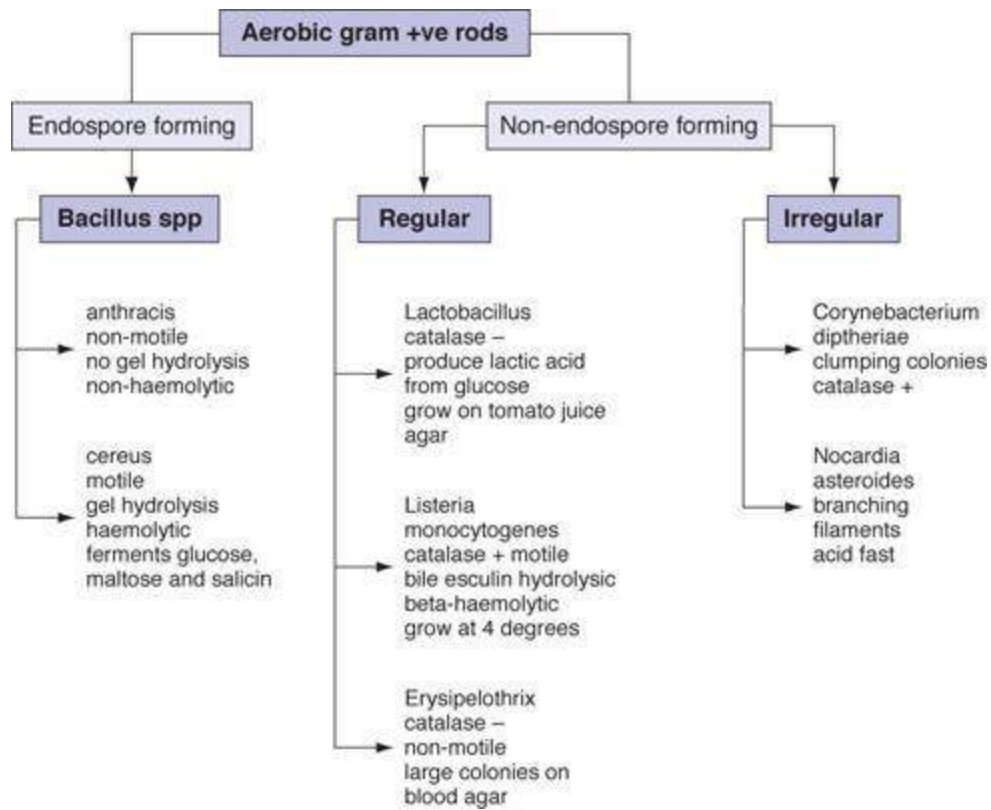
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○ Microbiology - Organisms

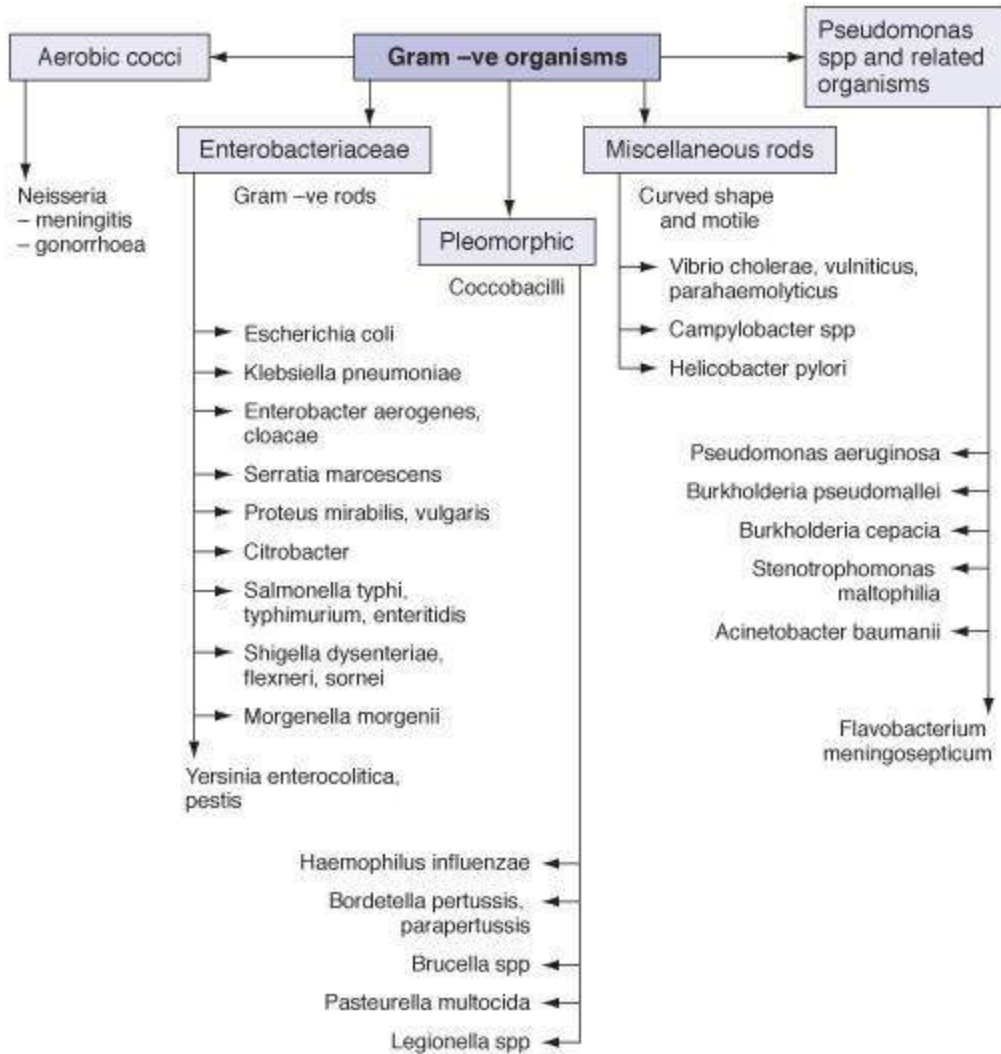
- *Bacteria*
- Taxonomy of medically important bacteria
- **Common aerobic gram-positive cocci**



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- **Common aerobic gram-positive rods**

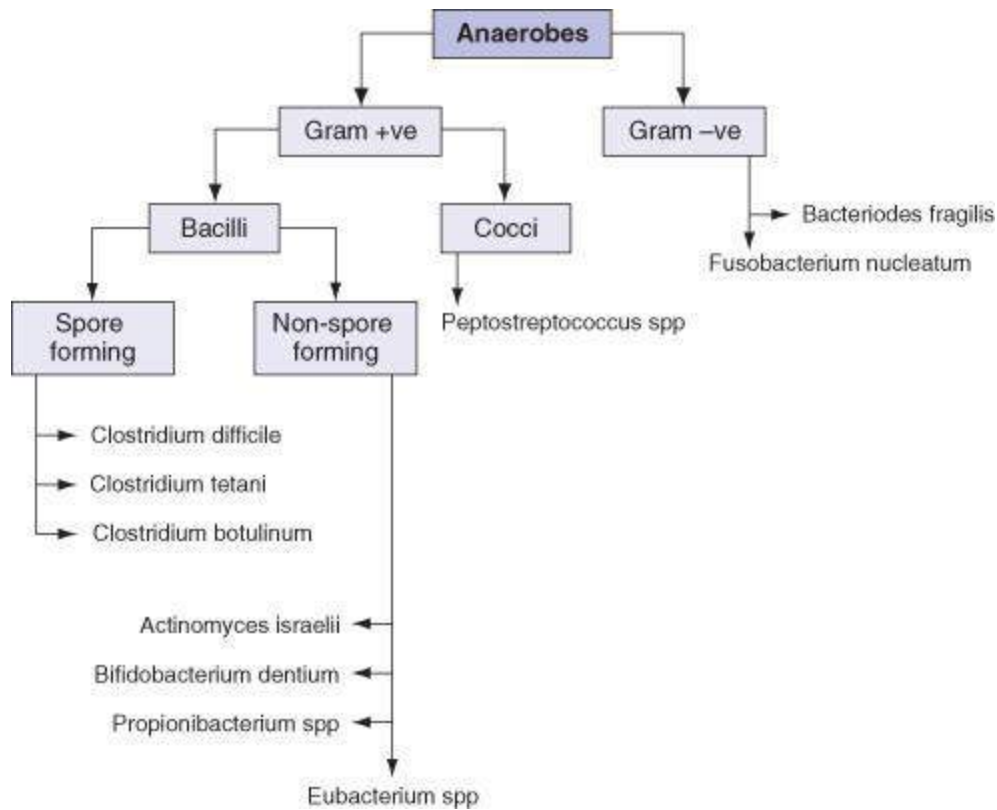


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-
- Common gram-negative organisms



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-
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Common anaerobic organisms



-
-
- **Multiresistant bacteria**

Organism	Characteristic
Hospital acquired MRSA (Methicillin resistant staphylococcus aureus)	<p>Penicillin-binding protein mutation coded by the mec-A gene on a transposon</p> <p>Confers cross-resistance to multiple classes of antibiotics (tetracyclines, macrolides, sulfonamides, aminoglycosides)</p> <p>Treatment includes Vancomycin, sometimes Rifampicin, Fusidic acid, Ciprofloxacin, Teicoplanin, Linezolid</p>
Community acquired MRSA	<p>Similar mechanism to hospital acquired MRSA conferred by mec-A plus an additional gene (e.g. PVL, PSM)</p> <p>More virulent infections are associated with toxic shock syndrome and necrotising pneumonia</p> <p>Treatment includes Vancomycin, sometimes Rifampicin, Fusidic acid, Ciprofloxacin, Teicoplanin, and Linezolid. Can be sensitive to Clindamycin, Bactrim, Erythromycin</p>
VISA (Vancomycin intermediate staphylococcus)	<p>Intermediate resistance of staphylococcus aureus to vancomycin, MIC required is much higher (4-8mcg/ml for VISA)</p>

aureus) also known as GISA (glycopeptide intermediate staphylococcus aureus)	<p>Genes code for factors such as additional peptidoglycan synthesis creating an unusually thickened cell wall containing dipeptides capable of binding vancomycin, and therefore reducing availability of the drug for intracellular target molecules</p> <p>Usually sensitive to Linezolid, Quinupristin-Dalfopristin, Daptomycin and Tigecycline</p>
VRSA (Vancomycin resistant staphylococcus aureus)	<p>Resistance of staphylococcus aureus to vancomycin, MIC is >16mcg/ml for VRSA</p> <p>Alterations in cell wall components coded by transposons, van A gene transferred from VRE</p> <p>Treated with Linezolid, Quinupristin-Dalfopristin, Co-trimoxazole, Chloramphenicol</p>
MRSE (Methicillin resistant staphylococcus epidermidis)	<p>Mec-A gene as per MRSA</p>
VRE (Vancomycin resistant enterococcus)	<p>Penicillin-binding protein mutations</p> <p>Beta-lactamase production</p> <p>Aminoglycoside modifying enzymes</p> <p>Antibiotic drug efflux pumps</p> <p>Alterations in cell wall components coded by transposons, described as Van A to F (A and B most common)</p> <p>Driven by widespread use of intravenous vancomycin resulting in sub-therapeutic levels in the bowel lumen.</p> <p>Treated with Linezolid, Chloramphenicol, Quinupristin-Dalfopristin (some E.faecium only)</p>
ESCAPPM group of gram-negative rods	<p>Enterobacter cloacae and aerogenes, Serratia, Citrobacter, Acinetobacter, Proteus vulgaris, Providencia, Morganella</p> <p>Rapidly inducible production of beta-lactamase during therapy with cephalosporins, especially third generation agents</p> <p>Treated with carbapenems or fourth generation cephalosporins</p>
ESBL (Extended spectrum beta-lactamases)	<p>Escherichia coli, Klebsiella pneumoniae, other enterobacteriaceae</p> <p>Genetically coded resistance to broad spectrum beta-lactam antibiotics: extended-spectrum</p>

	<p>penicillins, third generation cephalosporins, Aztreonam</p> <p>Co-resistance also often coded for co-trimoxazole, aminoglycosides and tetracyclines together, as well as separately for quinolones</p> <p>Treated with carbapenems or fourth generation cephalosporins</p> <p>In vitro these organisms appear sensitive to cephalosporins, but this is not the case in vivo</p>
Stenotrophomonas	<p>Intrinsic resistance to most beta-lactam antibiotics, including carbapenems and aminoglycosides due to two inducible enzymes: L1 (β-lactamase with broad activity against penicillins, carbapenems and cephalosporins) and L2 (cephalosporinase active against cephalosporins and monobactams) as well as enzyme modifiers and energy dependent efflux pumps</p> <p>Involved in VAP, surgical site infections or CRBSI</p> <p>Treated with Co-trimoxazole or fluoroquinolones (especially Moxifloxacin)</p>
Acinetobacter baumannii	<p>Carried in up to 25% of the population as normal skin flora, especially in moist areas such as the groin</p> <p>Persistent organism in the environment</p> <p>Can cause a wide range of nosocomial infections (pneumonia, catheter related blood stream infections, urinary tract infections, surgical site infections and meningitis)</p> <p>Resistant to many agents include broad-spectrum cephalosporins, penicillins, fluoroquinolones and aminoglycosides.</p> <p>Resistance is mediated by plasmid-mediated β-lactamases, chromosomal cephalosporinases, altered penicillin-binding proteins and membrane impermeability</p> <p>Treated with carbapenems. Outbreaks with resistance are noted, but treatment is often successful if two agents are used, even if in vitro resistance demonstrated</p> <p>Therefore should cover sensitive strains with two agents (e.g. a carbapenem and an aminoglycoside)</p>
Pseudomonas aeruginosa	<p>Intrinsically resistant to many antibiotics through efflux pumps, loss of porins, altered target enzymes (e.g. DNA gyrase), beta-lactamases, metallo-carbapenemases, aminoglycoside modifying enzymes</p> <p>Most active agents: Ciprofloxacin, Gentamicin, Tobramycin, Ceftazidime, Piperacillin-tazobactam, Ticarcillin-clavulanate, Imipenem, Meropenem, Amikacin</p>

	<p>Dual therapy using different antibiotic classes is recommended</p> <p>May have in vivo activity, despite in vitro resistance, especially if agents cycled</p> <p>Nebulised drugs (e.g. colistin) may be used as an adjuvant in chronic bronchiectasis</p>
Streptococcus pneumoniae	<p>Penicillin and cephalosporin show some intermediate and high level resistance</p> <p>Intermediate resistance may not equate with clinical treatment failure</p> <p>Vancomycin recommended for proven high resistance infections and for meningitis with gram-positive diplococci or suspected non-meningococcal disease</p>

○ **Other select bacteria**

Organism	Characteristic
Burkholderia pseudomallei	<p>Aerobic gram-negative bacillus</p> <p>Acquired from soil north of Rockhampton in Australia and Asia-Pacific region, especially during the wet season</p> <p>Causes pneumonia and abscesses especially spleen, prostate and skin</p> <p>Increased risk in alcoholics and diabetics</p> <p>Treated with co-trimoxazole plus meropenem/ceftazidime</p>
Salmonella spp. (<i>typhi</i> , <i>paratyphi</i> , <i>enteritidis</i> , <i>choleraesuis</i>)	<p>Aerobic gram-negative bacilli</p> <p>Causes Enteric (Typhoid) fever</p> <p>Faecal-oral spread</p> <p>Fevers, shock with relative bradycardia, abdominal pain, diarrhoea then constipation, GI bleeding and ileal perforation, rose spots on the trunk, hepatosplenomegaly</p> <p>Increased risk of severe metastatic disease in asplenia and sickle cell disease</p> <p>Treated with ciprofloxacin, ceftriaxone or azithromycin</p>

Bacillus anthracus	<p>Aerobic, Gram-positive bacilli, spore forming</p> <p>Acute infectious zoonosis or agent of bioterrorism</p> <p>Transmitted from inhalation, ingestion or contact with spores or skin lesions. No respiratory droplet spread</p> <p>Disease patterns:</p> <p>Pulmonary: haemorrhagic mediastinitis with lymphadenopathy and cardiorespiratory collapse</p> <p>Cutaneous: depressed black eschars</p> <p>GIT: bloody dysentery with shock</p>
Legionella spp.	<p><i>L.longbeachae</i> and <i>L.pneumophila</i> are the major causes of Legionella pneumonia in Australia</p> <p>Organisms are difficult to culture and usually require buffered charcoal yeast extract (BYCE) agar</p> <p>The urinary antigen test detects <i>L.pneumophila</i> serotypes I and II only</p>

○ **Obligate intracellular organisms**

Organism	Characteristic
Mycoplasma	<p>Mycoplasma pneumoniae: classical cause of a febrile illness with atypical pneumonia and rarely otitis media and sinusitis, rashes (e.g. Stevens Johnson Syndrome and Erythema nodosum), pancarditis, neurologic (e.g. transverse myelitis, aseptic meningoencephalitis, Guillain-Barre Syndrome) and haematologic manifestations (haemolytic anaemia, cold agglutinins with a procoagulant state)</p> <p>Mycoplasma hominis: causes pyelonephritis, pelvic inflammatory disease and post partum fever</p> <p>Ureaplasma urealyticum and Mycoplasma genitalium: causes of non-gonococcal urethritis</p>
Chlamydia spp.	<p>Previously known as Chlamydia</p> <p>A range of species cause human disease:</p> <p>Chlamydia pneumoniae (causes community acquired pneumonia and less often meningoencephalitis, arthritis, myocarditis and Guillain-Barre syndrome)</p>

Chlamydophila psittaci (transmitted from infected birds, usually parrots, to humans and causes psittacosis, a febrile illness with pneumonia, splenomegaly and a non-specific rash)

Chlamydophila trachomatis (common cause of pelvic inflammatory disease and trachoma, the most common cause of blindness world-wide, although most cases of eye disease occur in the tropics)

○ **Mycobacteria**

Organism	Characteristic
Mycobacterium tuberculosis	<p>Acid fast bacillus</p> <p>Exposure may result in:</p> <p>Immediate clearance</p> <p>Primary TB (Ghon focus and complex)</p> <p>Chronic TB infection without disease</p> <p>Secondary TB from reactivation: miliary TB and disseminated disease</p> <p>Isoniazid and Rifampicin resistance is increasing</p> <p>Standard course of therapy is Isoniazid (with pyridoxine) and Rifampicin for 6 months plus Ethambutol and Pyrazinamide for 2 months</p>
Mycobacterium avium complex	<p>Acid fast bacillus</p> <p>In immunosuppressed patients causes disseminated infection of leucocytes, liver, spleen, lymph nodes and the GI tract</p> <p>Treated with Clarithromycin/ azithromycin plus ethambutol/rifabutin</p>

○ **Protozoa**

Organism	Characteristic
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<p>Plasmodium spp (vivax, malariae, ovale, falciparum)</p>	<p>Causes malaria</p> <p>Transmitted from bites of female anopheles mosquitoes as sporozoites, which multiply in human bloodstream as merozoites. Then enter red cells and multiply as trophozoites which are released causing haemolysis</p> <p>Vivax and malariae have dormant hypnozoites in the liver</p> <p>Falciparum causes cerebral malaria and multiple organ failure</p> <p>Severe haemolysis with haemoglobinuria is called Blackwater fever</p> <p>Vivax is usually treated with chloroquine then primaquine for hypnozoite removal</p> <p>Falciparum is treated with quinine and increasingly with artemisin. Exchange blood transfusion is now rarely required</p>
<p>Toxoplasma gondii</p>	<p>Obligatory intracellular protozoan</p> <p>Multiplies in cats guts then the oocysts are excreted in cat faeces</p> <p>Invades new animal hosts (including humans) forming tissue cysts. Classically in retina and brain</p> <p>Human disease results from ingestion of cat faeces or uncooked meat from infected animals</p> <p>Usually asymptomatic or benign disease</p> <p>Severe illness seen in immunosuppressed patients, resulting from primary disease or re-activation. Produces ring enhancing lesion in liver, brain, heart, lungs</p> <p>Congenital syndrome can be seen if maternal primary disease in pregnancy</p> <p>Treated with Pyrimethamine + Sulfadiazine with folate</p>
<p>Entamoeba histolytica</p>	<p>Faecal-oral transmission</p> <p>Cause of dysentery, colonic and liver abscesses</p> <p>Treated with metronidazole and diloxanide for GI cyst destruction</p>
<p>Trichomonas vaginalis</p>	<p>Motile flagellate</p> <p>Sexual transmission</p> <p>Causes vulvovaginitis with a 'fishy' smelling discharge</p>

	Treat with metronidazole
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○ **Fungi**

Organism	Characteristic
Candida spp.	<p>Candida albicans: asexual, dimorphic with hyphae, pseudohyphae and chlamydospores</p> <p>Other species with increased resistance patterns and varied morphology include Candida tropicalis, krusei, parapsilosis, glabrata, lusitanae</p> <p>Up to 55% of critical care patients have been shown to be colonised by Candida species</p> <p>Invasive Candida infection is rare (2%), diagnosis difficult, and mortality high (35-65%)</p> <p>Common associations are antibacterial use, parenteral nutrition catheters, peritonitis and cerebral shunts</p> <p>Most infections are caused by Candida albicans, sensitive to fluconazole however azole resistance is increasing with albicans, and well established for krusei and glabrata</p> <p>Other antifungal agents used for resistant candida species: amphotericin, newer azoles like voriconazole, and echinocandins such as caspofungin</p>
Cryptococcus spp.	<p>Encapsulated organism</p> <p>Cause of meningitis and pneumonia in immunosuppressed patients</p> <p>India ink CSF staining and CSF and blood cryptococcal antigen tests are useful</p>
Mucormycosis	<p>Caused by Phycomycete fungi – Rhizopus, Rhizomucor, Absidia spp.</p> <p>Broad, non-septate hyphae that branch at 90 degrees</p> <p>Risk factors are chronic acidosis, poorly controlled diabetes, immunosuppression, renal failure, chelation therapy with increased serum iron levels, burns, intravenous drug abuse</p> <p>Invasive rhinocerebral, orbital or disseminated, black lesions</p> <p>Some are azole resistant</p>
Aspergillus fumigatus	<p>Acute angle, branching, septated, non-pigmented hyphae</p>

	<p>Associated diseases:</p> <p>Asthma - type 1 hypersensitivity to spores</p> <p>Allergic bronchopulmonary aspergillosis – type 3 hypersensitivity with recurrent pneumonia, bronchiectasis</p> <p>Aspergilloma (mycetoma)</p> <p>Invasive aspergillosis</p> <p>Serum Galactogamman (an aspergillus antigen) may aid diagnosis</p> <p>CT may show halo and crescent air signs with aspergilloma and invasive disease</p>
Pneumocystis jiroveci	<p>Previously known as Pneumocystis carinii and renamed recently and reclassified as a fungus (rather than a protozoan) based on nucleic acid and biochemical features</p> <p>Classically causes pneumonia in immunosuppressed patients</p> <p>May respond to treatment with trimethoprim-sulfamethoxazole, dapsone or atovaquone</p> <p>Concomitant corticosteroids should be used when initiating treatment in patients with HIV infection and significant hypoxaemia</p>

○ **Viruses**

Organism	Characteristic
Herpes viruses	<p>These are a leading cause of human viral disease, causing acute infections or diseases associated with reactivation after years of dormancy</p> <p>Agents include:</p> <p>Herpes simplex virus 1 & 2 (both can cause oral herpes labialis and herpes whitlow and meningoencephalitis); herpes 1 causes keratitis and herpes 2 genital herpes</p> <p>Cytomegalovirus (causes congenital disease and life threatening infections in immunosuppressed patients characterized by retinitis, interstitial pneumonia, hepatitis, colitis, oesophagitis and encephalitis)</p> <p>Ebstein Barr virus (causes Infectious mononucleosis or “Glandular fever”; also associated with Burkitt’s lymphoma, nasopharyngeal cancer and oral hairy leukoplakia in immunosuppressed patients)</p> <p>Varicella Zoster virus (causes Congenital Varicella syndrome, Chickenpox and Shingles with reactivation)</p>

	<p>Human herpes virus 6 (causes roseola infantum – also called Exanthum subitum)</p> <p>Human herpes virus 8 (associated with Kaposi's sarcoma)</p>
HIV	<p>Lentivirus, a subgroup of retroviruses</p> <p>Over 70% of transmission is sexual (more heterosexuals than homosexuals infected worldwide) with some parenteral (e.g. intravenous drug abusers, health care worker needle stick injury) and perinatal infection</p> <p>Causes a non-specific seroconversion illness followed eventually by opportunistic infections when CD4 count falls below 200cells/mm³ (e.g. candidiasis, cytomegalovirus, Pneumocystis jiroveci, Tuberculosis, Mycobacterium avium complex) and the Acquired Immune Deficiency Syndrome (AIDS) characterized by more severe infections including toxoplasmosis and cryptococcal meningitis, malignancies (e.g. Kaposi's sarcoma, B cell lymphomas, cervical cancer) and major neurological illnesses (e.g. progressive multifocal leukoencephalopathy due to JC virus and AIDS dementia complex).</p> <p>Treatment is complex with a combination of highly active antiretroviral treatment (HAART) and prophylaxis for opportunistic pathogens</p>
Influenza A and B	<p>A group of RNA viruses</p> <p>Influenza A causes a range of illnesses from mild upper respiratory tract infections to viral pneumonia that may be rapidly fatal or complicated by secondary bacterial pneumonia</p> <p>Influenza B usually causes a minor illness</p> <p>The main role of antiviral agents is to reduce the duration of infectivity</p> <p>Epidemic and pandemic "flu" like illnesses</p> <p>Epidemics involve large numbers of a population and pandemic large numbers of populations across the world</p> <p>A number of viruses have threatened population with manifestations ranging from coryzal symptoms to febrile illnesses with constitutional symptoms to life threatening respiratory failure</p> <p>Severe Acute Respiratory Syndrome (SARS): identified as a corona virus</p> <p>Highly Pathogenic Avian Influenza (H5N1)</p> <p>Swine Influenza (H1N1)</p> <p>Treatment is largely supportive with antiviral agents to reduce severity and duration of symptoms (oseltamivir, zanamivir)</p>

Dengue	<p>Flavivirus transmitted by Aedes mosquitoes</p> <p>Classic dengue fever: mild febrile illness with retroorbital pain, arthralgia, myalgia</p> <p>Dengue Haemorrhagic fever/Shock syndrome with re-exposure</p>
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○ **Parasites**

Organism	Characteristic
Echinococcus granulosus	<p>Tapeworms: cestodes</p> <p>Ingestion of canine parasites from dog faeces usually in rural areas</p> <p>Large complex cysts in solid organs causing anaphylaxis if contents spill</p> <p>Treated with surgery and albendazole</p>
Strongyloides stercoralis	<p>Roundworms: nematodes</p> <p>Percutaneous transmission in tropics/subtropics</p> <p>Cause of cutaneous larva migrans and metastatic lesions in immunosuppressed patients, especially those on corticosteroid therapy</p>

○ **Rickettsiae**

Organism	Characteristic
<p>Gram-negative obligate intracellular arthropod parasites</p> <p>e.g. Scrub typhus (R. tsutsugamushi): rodents</p> <p>e.g. Endemic typhus (R.</p>	<p>Human infection from arthropod bites or inhaled faeces, with multiplication in endothelial cells</p> <p>Cause febrile exanthematous diseases</p> <p>Treated with doxycycline, ciprofloxacin, clarithromycin, co-trimoxazole</p>

typhi): fleas	
e.g. Queensland Tick typhus (T. australis): ticks	

○ **Spirochaetes**

Organism	Characteristic
Treponema pallidum	<p>Causes Syphilis:</p> <p>Primary: painless chancre</p> <p>Secondary: fever, lymphadenopathy, Condyloma lata, 'snail-track' buccal ulcers</p> <p>Tertiary: gummas</p> <p>Quaternary: aortic dilatation, General paresis of the insane, tabes dorsalis with Charcot's joints and Argyll-Robertson pupils, meningovascular disease</p> <p>Congenital syndrome</p> <p>Treated with penicillin or doxycycline. Jarisch-Herxheimer reaction with first dose from massive endotoxin release</p>
Leptospira interrogans	<p>Acquired from contact with rat urine</p> <p>Causes a febrile illness with hepatitis, conjunctivitis, myositis, myocarditis, meningitis, purpura, coagulopathy with bleeding, cutaneous eschars</p> <p>Treated with penicillin or doxycycline</p>

Microbiology - Differential diagnosis for common infections

Infection	Causative organisms
Endocarditis	<p>Staphylococci (aureus, lugdenensis)</p> <p>Streptococci (viridans, sanguis)</p> <p>Enterococci</p> <p>HACEK group of oral gram-negative bacilli:</p> <ul style="list-style-type: none"> - Haemophilus parainfluenzae, aphrophilus - Actinobacillus actinomycetemcomitans - Cardiobacterium hominis - Eikenella corrodens - Kingella kingae <p>Coxiella burnetti</p> <p>Legionella spp</p> <p>Bartonella spp</p> <p>Pseudomonas aeruginosa</p> <p>Neisseria gonorrhoea</p> <p>Corynebacterium diphtheriae</p> <p>Fungi</p>
Pneumonia	<p>Streptococcus pneumoniae</p> <p>Haemophilus influenzae</p> <p>Staphylococcus aureus (complicating Influenza, alcoholism, IVDU)</p> <p>Pseudomonas aeruginosa (bronchiectasis)</p> <p>Klebsiella pneumoniae and other gram-negative bacilli (alcoholism)</p>

	<p><i>Moraxella catarrhalis</i></p> <p>Anaerobes (aspiration, IVDU, alcoholism, poor dentition, nursing homes)</p> <p><i>Legionella</i> spp. (underlying cardiorespiratory disease)</p> <p><i>Mycoplasma pneumoniae</i></p> <p><i>Chlamydia pneumoniae</i></p> <p>Viruses: Influenza A, B, Parainfluenza 1,2,3,</p> <p>Adenovirus, Respiratory Syncytial Virus, Varicella Zoster Virus</p>
Meningitis	<p><i>Streptococcus pneumoniae</i></p> <p><i>Neisseria meningitidis</i></p> <p><i>Haemophilus influenzae</i></p> <p><i>Listeria monocytogenes</i> (age extremes)</p> <p><i>Streptococcus agalactiae</i> (neonates)</p> <p><i>Escherichia coli</i> (neonates)</p> <p><i>Staphylococcus</i> spp. and gram-negative bacilli (skull trauma or neurosurgery)</p> <p><i>Mycobacterium tuberculosis</i></p> <p><i>Cryptococcus neoformans</i> (immunosuppressed)</p> <p>Enteroviruses</p> <p>Coxsackie viruses</p> <p>Arboviruses (e.g. Ross river and Dengue viruses)</p> <p><i>Leptospira interrogans</i></p> <p><i>Brucella</i> spp</p>

	<p><i>Borrelia burgdorferi</i></p> <p><i>Treponema pallidum</i></p>
Encephalitis	<p>Herpes simplex virus</p> <p>Cytomegalovirus</p> <p>Ebstein Barr virus</p> <p>Human herpes virus type 6</p> <p>Arboviruses</p> <p>Coxsackie viruses</p> <p>Enteroviruses</p> <p>Echoviruses</p> <p>Adenovirus</p> <p>Influenza viruses</p> <p>Hepatitis A virus</p> <p>Japanese encephalitis</p> <p>HIV</p> <p><i>Toxoplasma gondii</i></p> <p><i>Plasmodium falciparum</i></p> <p><i>Rickettsiae</i></p> <p><i>Borrelia burgdorferi</i></p> <p>Creutzfeldt-Jacob disease</p> <p>Rubella (Progressive rubella panencephalitis)</p> <p>Measles (Subacute sclerosing panencephalitis)</p>
Impaired immunoglobulin production including post-splenectomy	Encapsulated bacteria mainly:

	<p><i>Streptococcus pneumoniae</i>, <i>pyogenes</i></p> <p><i>Enterococcus</i> spp</p> <p><i>Neisseria meningitidis</i> and gonorrhoea</p> <p><i>Haemophilus influenzae</i></p> <p><i>Salmonella</i> spp.</p> <p><i>Capnocytophaga canimorsus</i></p> <p><i>Bacteroides</i> spp.</p> <p><i>Plasmodium</i> spp. and other parasites</p>
Impaired cell-mediated immunity (AIDS, immunosuppressive therapy)	<p><i>Pneumocystis jirovecii</i>, <i>Toxoplasma gondii</i></p> <p>Cytomegalovirus</p> <p>Herpes simplex virus</p> <p>Varicella-zoster virus</p> <p>Fungi: <i>Candida albicans</i></p> <p><i>Mycobacterium tuberculosis</i></p> <p><i>Mycobacterium avium</i> complex</p> <p><i>Legionella</i> spp.</p> <p><i>Mycobacterium</i> spp.</p> <p><i>Streptococcus pneumoniae</i></p> <p><i>Strongyloides stercoralis</i></p>
Impaired neutrophil number and/or function	<p>Gram-negative bacilli</p> <p><i>Staphylococcus aureus</i></p> <p><i>Streptococcus viridans</i></p>

	Fungi: Candida, Aspergillus, Mucormycosis
Necrotising fasciitis (termed Fournier's gangrene if involves perineum)	Type 1: Mixed infection including gram-negative enteric bacilli, Vibrio spp., and anaerobes Type 2: Gram-positive infection, Group A streptococci, Staphylococcus aureus
Myonecrosis (gas gangrene)	Clostridium perfringens or septicum
Toxin mediated exfoliating shock syndromes	Staphylococcal scalded skin syndrome: Staphylococcus aureus group 2: type 71 with production of exfoliative toxins. Usually associated with occluded mucosal surfaces (e.g. nasal packs, tampons). Streptococcal toxic shock syndrome: Group A Streptococcus with pyrogenic exotoxins which act as superantigens with non-specific T cell activation. Usually soft tissue infections. Immunoglobulin may improve survival. Clindamycin may reduce toxin production.
Pelvic inflammatory disease	Usually polymicrobial with a range of pathogens including endogenous flora including anaerobes Sexually acquired: Chlamydia trachomatis, Neisseria gonorrhoea Non-sexually acquired: Mycoplasma hominis, Ureaplasma urealyticum, Actinomyces (if IUCD)
Dysentery	Shigella spp. Salmonella spp Campylobacter spp Yersinia enterocolitica Enterohaemorrhagic E.coli Entamoeba histolytica
Neck infections	Ludwig's angina: sublingual/ submaxillary space infection Retropharyngeal and parapharyngeal space infections: can

	<p>complicate foreign bodies and perforations with instruments</p> <p>These are infections with mixed oral flora with gram-positive, negative and anaerobic organisms</p> <p>Lemierre's syndrome: retrotonsillar infection with the anaerobe <i>Fusobacterium necrophorum</i> which enters the jugular vein and disseminates</p>
Animal contact	<p><i>Chlamydia psittaci</i> (handling excreta of parrots, chicken and turkeys giving pneumonia)</p> <p><i>Coxiella burnetii</i>: Q fever (parturent stock animals and hides producing pneumonia)</p> <p><i>Brucella</i> spp. (stock animals and their milk: pneumonia)</p> <p><i>Francisella tularensis</i> (stock animal carcasses: pneumonia)</p> <p><i>Pseudomonas mallei</i> (horses: pneumonia)</p> <p>Leptospirosis (rats)</p> <p><i>Toxoplasma gondii</i> (cats)</p> <p>Hydatid disease (dog faeces)</p> <p>Cysticercosis (infected meat)</p> <p>- Pork: <i>Taenia solium</i></p> <p>- Beef: <i>Taenia saginata</i></p> <p><i>Bacillus anthracis</i> (wool)</p>
Bites	<p><i>Staphylococcus aureus</i></p> <p><i>Streptococcus</i> spp</p> <p>Anaerobes including <i>Clostridium tetani</i></p> <p><i>Eikenella corrodens</i> (human)</p> <p><i>Pasteurella</i> (cats and dogs)</p>

	<p>Capnocytophaga canimorsus (cats and dogs)</p> <p>Bartonella henselae (cat scratch)</p> <p>Lyssa virus (bats)</p>
Waterborne agents	<p>Aeromonas spp. (fresh water)</p> <p>Shewanella putrefaciens (salt water)</p> <p>Vibrio spp (warm salt water e.g. vulnificus)</p> <p>Pseudomonas aeruginosa (spa baths)</p> <p>Legionella spp (water tanks)</p>

Microbiology - Antimicrobial therapy

Antibacterial agents

Drug(s)	Class	Mechanism	Spectrum	Specific side-effects**
<p>Gentamicin*#</p> <p>Tobramycin*#</p> <p>Amikacin*#</p>	Aminoglycoside	Bacterial protein synthesis inhibitor via binding to 30s ribosome.	Aerobic gram-negatives including Pseudomonas. Synergistic with cell wall inhibitors.	Nephrotoxic, Ototoxic, Peripheral neuritis, Neuromuscular blockade
<p>Ciprofloxacin*</p> <p>Norfloxacin*</p> <p>Moxifloxacin</p> <p>Gatifloxacin</p>	Quinolone	Inhibits DNA gyrase needed for protein synthesis.	Predominant Gram-negative cover. Ciprofloxacin has reliable Pseudomonas cover but no anaerobic or reliable gram-positive cover. Moxi/Gati have good anaerobic, extended gram-positive cover (including Streptococci), intracellular	Growing cartilage damage, Achilles tendonitis, Nephritis, CNS stimulation. Hypoglycaemia with Gatifloxacin QT prolongation

			organisms of atypical pneumonia cover but less reliable Pseudomonas cover.	
Phenoxymethyl penicillin Benzyl penicillin*	Narrow spectrum penicillin	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Inactivated by beta-lactamases thus most Staphylococci are resistant. Mainly gram-positive cover Streptococcus pneumoniae resistance increasing. Penicillins are active against Listeria.	Pseudomembranous colitis, Leucopaenia, CNS stimulation – seizures especially in renal failure, Interstitial nephritis.
Flucloxacillin* Dicloxacillin*	Narrow spectrum penicillin with anti-staphylococcal cover	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Beta-lactamase resistant thus improved Staphylococcal cover	Flucloxacillin (more than dicloxacillin) causes cholestatic jaundice.
Ampicillin* Amoxycillin*	Moderate spectrum penicillin	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Improved activity against aerobic gram-negative bacilli. Beta-lactamase sensitive thus poor Staphylococcal cover and increasing gram-negative resistance.	Rash if acute EBV infection.
Amoxycillin-clavulanate* Ticarcillin-clavulanate* Piperacillin-tazobactam*	Broad spectrum penicillin	Bacterial cell wall inhibitor via impaired transpeptidase cross linking	Combination with beta-lactamase inhibitors confers broad activity against gram-positives including Staphylococci and Streptococci, anaerobes and aerobic gram-negative bacilli. Ticarcillin-clavulanate and Piperacillin-	Platelet dysfunction and salt loading with Ticarcillin-clavulanate.

			tazobactam have good Pseudomonas cover. Piperacillin-Tazobactam has superior Enterococcal cover.	
Cephalexin* Cephazolin* Cephalothin*	First generation cephalosporin	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Beta-lactamase resistant with gram-positive cover and some activity against gram-negative bacilli. All are inducible Extended Spectrum Beta-Lactamase (ESBL) producers. Cephalosporins all ineffective against Listeria and enterococcus.	3-6% cross-reactivity of cephalosporins with penicillin. Disulfiram-like reaction with cephazolin.
Cefaclor* Cefuroxime*	Second generation cephalosporin with anti-Haemophilus cover	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Improved gram-negative cover including against Haemophilus.	
Cefotetan* Cefoxitin*	Second generation cephalosporin	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Additional anaerobic activity.	Coagulopathy and disulfiram-like reaction with cefotetan.
Ceftriaxone Cefotaxime* Ceftazidime*	Third generation cephalosporin	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Reduced gram-positive but improved gram-negative activity with good CSF penetration. Ceftazidime has good Pseudomonas cover.	Disulfiram-like reaction with ceftriaxone.
Cefepime* Cefpirome*	Fourth generation cephalosporin	Bacterial cell wall inhibitor via impaired transpeptidase cross-linking.	Improved gram-positive cover. Reliable Pseudomonas activity.	
Imipenem -	Carbapenem	Bacterial cell	Broad anaerobic,	Hepatitis,

cilastatin* Meropenem* Ertapenem*		wall inhibitor.	gram-positive and gram negative cover including Pseudomonas. Ertapenem has poor Pseudomonas cover Inactive against Enterococcus.	CNS stimulation.
Aztreonam*	Monobactam	Bacterial cell wall inhibitor.	Aerobic gram-negatives including Pseudomonas.	Phlebitis, Hepatitis, Thrombocytopaenia.
Teicoplanin* Vancomycin*#	Glycopeptide	Bacterial cell wall inhibitor and inhibition of bacterial protein synthesis.	MRSA, MRSE Gram-positives but less effective than anti-staphylococcal penicillins. Good cover against penicillin resistant Streptococcus pneumoniae. Clostridium difficile colitis.	'Red man' syndrome from histamine release, Nephrotoxic, Ototoxic, Neuromuscular blockade.
Clindamycin Lincomycin*	Lincosamide	Bacterial protein synthesis inhibitor via 50s ribosome.	Gram-positive infections and anaerobes. No reliable gram-negative cover. High bone, bile and urine concentrations.	Classical cause of Pseudomembranous colitis, Leucopaenia, Thrombocytopaenia, Neuromuscular blockade.
Erythromycin* Azithromycin Clarithromycin* Roxithromycin	Macrolide	Bacterial protein synthesis inhibitor via 50s ribosome.	Gram-positive, anaerobes and some non-enteric gram-negative infections. Intracellular organisms. Azithromycin has reduced gram-positive activity and cover against atypical mycobacteria and Toxoplasma gondii. Clarithromycin active against Helicobacter pylori and Mycobacterium	Erythromycin has multiple drug interactions – long QT and monomorphic VT, increases levels of digoxin, warfarin, theophylline, cyclosporine. Erythromycin causes pancreatitis and nephrotoxicity. Azithromycin causes nephritis. Thrombocytopaenia with Clarithromycin. Hepatitis with all.

			avium complex.	
Metronidazole* Tinidazole	Nitroimidazole	Reduced intracellularly in anaerobes to a cytotoxic agent that interacts with DNA and inhibits bacterial protein synthesis.	Anaerobes and protozoa including Trichomonas, Giardia and Entamoeba.	Leucopaenia, Altered taste CNS stimulation, Disulfiram-like reactions.
Sulfamethoxazole + Trimethoprim*	Sulfonamides & combination agents	<p>Inhibition of bacterial synthesis of tetrahydrofolate.</p> <p>Sulfonamides inhibit dihydrofolate synthetase.</p> <p>Trimethoprim inhibits dihydrofolate reductase.</p>	Combination used for: Pneumocystis jiroveci, Stenotrophomonas maltophilia, Listeria monocytogenes, Nocardia spp. Trimethoprim active against some gram-negative bacilli.	Sulfonamides: Multiple drug interactions – increases levels of warfarin, phenytoin, cyclosporin. Nephritis, Hypoglycaemia, Stevens Johnson syndrome, Haemolytic anaemia (especially in G-6-PD deficiency), Thrombocytopenia, Stomatitis, Arthritis, Conjunctivitis.
Tetracycline* Doxycycline Minocycline	Tetracycline	Bacterial protein synthesis inhibitor via 30s ribosome.	Gram-positive and gram-negative cover but problematic widespread resistance. Good cover against Chlamydia, Mycoplasma, Rickettsiae, Spirochaetes, Brucella, Coxiella burnetti.	Oesophagitis (Doxycycline), tooth discolouration in children, photosensitivity, vestibular reactions and benign intracranial hypertension (especially minocycline), Pancreatitis, Hepatitis.
Tigecycline	Glycylcyclines	Bacterial protein synthesis inhibitor via 30S ribosome	Gram positive and gram negative and anaerobic cover including MRSA and Acinetobacter. No activity against Pseudomonas or Proteus spp	Nausea, vomiting diarrhoea Tooth discolouration in children

Rifampicin* Rifabutin*	Rifamycin	Inhibit bacterial RNA synthesis by binding to DNA-dependant RNA polymerase	Gram-positive (including Staphylococci) and gram-negative bacteria (including Neisseria meningitidis and Haemophilus influenzae). Mycobacteria tuberculosis and atypical mycobacteria.	Rapid emergence of resistance. Multiple drug interactions - reduces levels of warfarin, oral contraceptives, cyclosporin. Orange discolouration of secretions Hepatitis Nephritis Thrombocytopaenia
Linezolid	Oxazolidinone	Bacterial protein synthesis inhibitor via 50s ribosome	Gram-positive cover including MRSA, MRSE, VRE Intracellular organisms Poor anaerobic and gram-negative cover	Bone marrow suppression MAOI activity with hypertensive crises with catecholamines and serotonin syndrome with serotonergic agents
Quinupristin - Dalfopristin	Streptogramin	Bacterial protein synthesis inhibitor - Quinupristin inhibits 50s ribosome and Dalfopristin interferes with peptidyl transferase	Gram-positive bacilli – Enterococcus faecium Gram-negative aerobes – limited to Neisseria and Moraxella spp Intracellular organisms Poor CNS penetration	Phlebitis Myalgia Arthralgia

* Designates drugs requiring dose adjustments in patients with impaired renal function

Designates recommendation for routine monitoring of drug levels

** All antibacterial agents may cause allergic and anaphylactic reactions, fever, GIT intolerance and predispose to candidiasis and pseudomembranous colitis

Antifungal agents

Drug(s)	Class	Mechanism	Spectrum	Comments
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Fluconazole	Triazole	Inhibit ergosterol synthesis in the fungal cell wall by inhibiting lanosterol demethylase	C. albicans Cryptococcus	Renal excretion All azoles may cause: Hepatotoxicity Anaemia Thrombocytopaenia Leucopaenia Stevens Johnson syndrome Multiple drug interactions - increases levels of phenytoin, warfarin, cyclosporin.
Itraconazole	Triazole	Inhibit ergosterol synthesis in the fungal cell wall by inhibiting lanosterol demethylase	C. albicans Cryptococcus Aspergillus (in high doses) Scedosporium	Liver excretion Hypertension Hypokalaemia
Voriconazole Ravuconazole Posaconazole	Triazole	Inhibit ergosterol synthesis in the fungal cell wall by inhibiting lanosterol demethylase	C. albicans C. glabrata C. krusei Cryptococcus Aspergillus (in high doses) Scedosporium	Liver excretion Visual changes
Amphotericin	Polyene	Combines with sterols in fungal membrane to create a channel with leakage of cytosol	All Candida spp except C. lusitanae Cryptococcus Aspergillus Mucor Scedosporium	Various formulations with reducing toxicity (liposomal < lipid complex < colloidal suspension < parent drug). Side-effects: Fevers, chills, myalgia, back pain Dysrhythmias Seizures Renal toxicity – acute renal failure, renal tubular acidosis, Na and K wasting Peripheral neuropathy Pancytopenia
Nystatin	Polyene	Combines with sterols in fungal membrane to create a channel with leakage of		Topical treatment only limits role to mucocutaneous C. albicans therapy

		cytosol		
Caspofungin, Micafungin Anidulafungin	Echinocandin	Inhibits synthesis of D-glucan a key fungal cell wall component.	All Candida spp Aspergillus – less active than Amphotericin.	Can cause elevated LFTs No activity against Cryptococcus or Scedosporium spp (can mimic Invasive aspergillosus).
Flucytosine	Antimetabolite	Converted to fluorouracil in fungal cells and interferes with pyrimidine metabolism with reduced protein synthesis	Cryptococcus Candida spp	Better alternatives as serious side-effects: Bone marrow suppression CNS stimulation Hepatitis Photosensitivity

Antiviral agents

Drug(s)	Class	Mechanism	Spectrum	Side-effects
Aciclovir Valaciclovir Famciclovir	Guanosine analogue	Converted to a triphosphate which inhibits DNA polymerase inhibiting viral replication	Herpes simplex Varicella zoster virus (less effect)	Crystalluria and acute renal failure CNS stimulation Phlebitis GI disturbance Pancytopenia can occur with Valaciclovir Newer agents have longer half lives
Ganciclovir Valganciclovir	Guanosine analogue	Converted intracellularly to a triphosphate that inhibits viral DNA polymerase inhibiting viral replication. Valganciclovir	Cytomegalovirus	Pancytopenia GI disturbance CNS stimulation Phlebitis Carcinogenic

		is the valine ester prodrug of Ganciclovir – permits once daily oral dosing.		
Amantadine Rimantadine	Mixed agent - Anti-influenza A and anti-Parkinsonian effects (blocks MAOI and NMDA receptors)	Inhibits M2 membrane protein ion channel activity inhibiting viral replication Increases dopamine, serotonin, noradrenaline	Influenza A	Insomnia Nervousness Blurred vision Seizures
Oseltamivir Zanamivir	Neuraminadase inhibitor	Prevents release of new viral particles	Influenza A, B	Nausea and vomiting Headaches Diarrhoea Bronchospasm with inhaled Zanamivir Oseltamivir generally well tolerated
Lamivudine Zidovudine Stavudine Didanosine Zalcitabine	Nucleoside analogue reverse transcriptase inhibitor (NARTI's)*	Inhibit viral replication	Hepatitis B (Lamivudine) HIV	Mitochondrial DNA polymerase inhibition may cause lactic acidosis and fat wasting Nausea Pancreatitis Peripheral neuropathy Neutropaenia
Tenofovir	Nucleotide analogues*	Inhibit viral replication	HIV	Nausea
Nevirapine Efavirenz Delavirdine	Non-nucleoside reverse transcriptase inhibitor*	Inhibits viral replication	HIV	Many drug interactions as metabolised by cytochrome P450 Neuropsychiatric disturbances

Nelfinavir Ritonavir Saquinavir Indinavir Lopinavir Amprenavir	Protease inhibitor*	Inhibit viral replication	HIV	Many drug interactions as metabolised by cytochrome P450 Nausea and diarrhoea Headaches Elevated lipids and glucose Lipodystrophy and atrophy
Interferon Alpha-2a and 2b Beta 1b	Interferon	Inhibits viral replication and complex immune modulation	Alpha-2a: Hepatitis B, C CML Hairy cell leukaemia Kaposi's sarcoma Alpha-2b: Hepatitis B, C Condyloma accuminata Hairy cell leukaemia Kaposi's sarcoma Beta-1b: Multiple sclerosis Infections in chronic granulomatous disease	Leucopaenia Thrombocytopaenia Alopecia Myalgia Depression Irritability Retinal and pulmonary abnormalities
Ribavirin	Guanosine analogue	Inhibits viral replication and may block virus from re infecting new cells	Aerosolised for RSV. Combination therapy with interferon alpha-2b.	Haemolytic anaemia Birth defects

* For HIV usually a combination of two NARTI's plus a protease inhibitor or non-NARTI

Transcranial doppler studies

Transcranial Doppler

Overview on TCD

Transcranial Doppler (TCD) ultrasonography uses a hand-held Doppler transducer placed on the cranial skin to measure the pulsatility and velocity of blood flow within the intracranial and extracranial arteries. There are three naturally occurring acoustic windows on the skull: at the transtemporal, transorbital and transforaminal sites. TCD is attractive, as a simple, non-invasive test that can be performed repeatedly at the bedside. Like all sonographic investigations it is operator dependent and there can be inter-observer variability. At present the main applications in

the ICU are for: the evaluation of vasospasm in patients with subarachnoid haemorrhage; the assessment of brain death and the monitoring of cerebral blood flow in head injury.

TCD Normal values

Artery	Window	Depth (mm)	Velocity (cm/s)
Ophthalmic artery	orbital	40-50	16-26
Middle cerebral artery	temporal	35-60	46-86
Anterior cerebral artery	temporal	60-75	41-76
Posterior cerebral artery	temporal	60-75	33-64
Vertebral artery	foraminal	45-75	27-55
Basilar artery	foraminal	70-120	30-57

A mean flow velocity greater than 120 cm/second is considered abnormal.

Lindegaard ratio: This is a derived value that is used to distinguish between vasospasm and hyperaemia as they can both cause an elevated flow velocity. The ratio of flow velocity in the middle cerebral artery to that in the external carotid artery increases with worsening vasospasm. The normal value for this ratio (LR-Lindegaard ratio) is 1.1-2.3. In the context of an elevated flow velocity a ratio lower than 3 is interpreted as hyperaemia; 3-6 as mild vasospasm and >6 severe vasospasm.

Pulsatility index: this is another derived value. The resistance of distal cerebral vasculature is reflected by the 'pulsatility' of the flow velocity waveform. A strong correlation exists between the pulsatility index and the ICP (in the ICP range of 5-40mmHg).

Utility of TCD

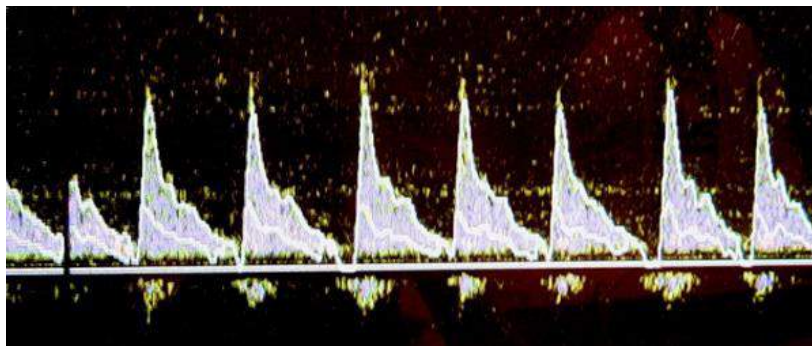
As intracranial pressure rises, TCD waveforms show high-resistance profiles. Firstly with low, then zero and finally reversed diastolic flow velocity.

The role of transcranial Doppler in the critically ill remains controversial. Potential applications for this modality are numerous. Some centres screen patients with subarachnoid haemorrhage routinely for signs of vasospasm and tailor interventions to the findings. Candidates have been asked to interpret transcranial Doppler data. Insonation of the Doppler signal along the middle cerebral artery (MCA velocity) is most commonly performed. The Lindegaard ratio (ratio of velocity in the middle cerebral to internal carotid artery) is also commonly calculated.

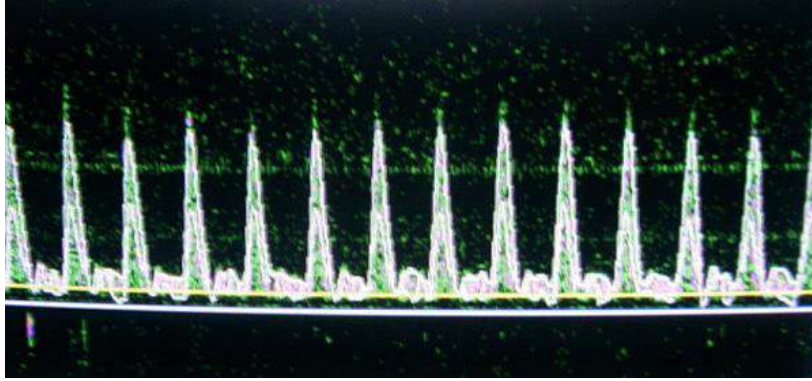
Abnormal TCD findings

Condition	Findings
Vasospasm in a subarachnoid haemorrhage	<p>Increased mean MCA velocity and increased Lindegaard ratio</p> <p>Normal: velocity (<120 cm/sec), ratio (<3)</p> <p>Mild vasospasm: velocity (120–200 cm/sec), ratio (3–6)</p> <p>Severe vasospasm: velocity (>200 cm/sec), ratio (>6)</p>
Brain stem death	<p>Absent diastolic or reverberating flow pattern with short forward systolic then short early diastolic retrograde flow</p> <p>Small systolic peaks in early systole</p> <p>Systolic-only flow or retrograde diastolic flow</p>

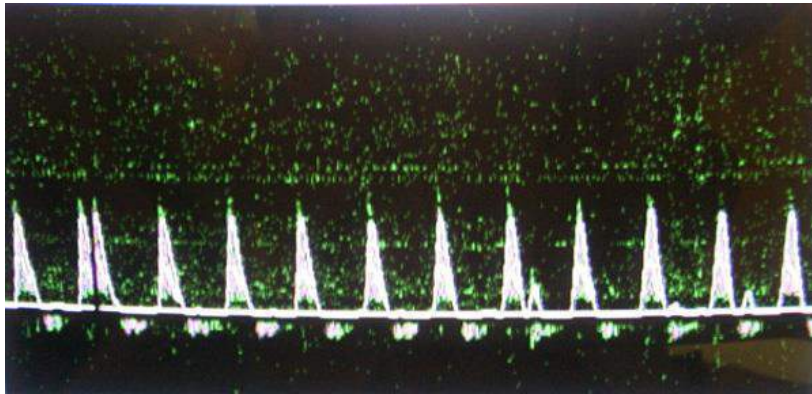
Transcranial Doppler abnormalities



(a) TCD of the middle cerebral artery (MCA) in a patient with a severe head injury and raised intracranial pressure. Note the low diastolic velocity and high perfusion index (PI). (Peak MCA velocity = 59 cm/s; mean MCA velocity = 38 cm/s; depth = 60 mm; PI = 2.75)



(b) ICP continues to increase, along with the PI, further limiting diastolic flow. (Peak) MCA velocity = 55 cm/s; mean MCA velocity = 12 cm/s; depth = 60mm; PI = 3.65.)



(c) Eventually, flow reversal occurs during diastole. (Peak MCA velocity = 28 cm/s; mean MCA velocity = 7 cm/s; depth = 60mm; PI = 4.40.)

Electroencephalography

Electroencephalography (EEG)

EEG overview

Electroencephalographic recording may assist in the assessment of the ICU patient with unexplained impairment of consciousness. These provide some clues for diagnosis but few are pathognomonic.

Prolonged EEG monitoring, usually with concurrent video recording, is occasionally necessary, especially to address the question of subclinical or subtle epileptic seizures. The EEG appearance of electrographic seizures is highly variable, and a serious consideration of this topic is beyond the scope of this book. Suffice to say that ictal discharges are typically rhythmic and demonstrate evolution in frequency and spatial distribution over the course of the seizure.

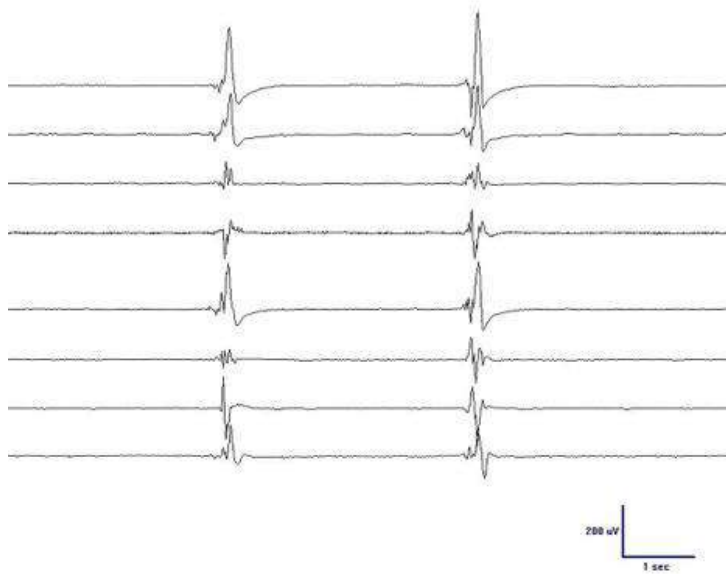
EEG patterns

Pattern	Interpretation	Possible ICU diagnoses
Posterior alpha (8-13 Hz) background activity, attenuated by eye-opening	Normal awake adult	Psychogenic seizures (pseudoseizures) Psychogenic coma (pseudocoma)
Coma patterns: non-reactive (monotonous) diffuse activity (several types: e.g., alpha coma, beta coma, theta coma) burst-suppression pattern (flat-line tracing interrupted by bursts of sharply contoured activity)	Poor prognosis for meaningful neurologic recovery (in absence of reversible factors) Assess clinical and EEG reactivity to auditory, tactile, photic	Drugs Hypoxic-ischemic encephalopathy
Electrocerebral inactivity/silence (ECI/ECS): flat-line tracing	Absence of synchronized neuronal activity	Drugs Hypothermia Brain death
Generalized slowing: theta (4-7 Hz) and/or delta (<4 Hz)	Diffuse cerebral dysfunction	Diffuse encephalopathy
Focal slowing: theta or delta frequency	Focal cerebral dysfunction	Tumor Stroke

Asymmetry: lateralized difference in amplitude of background activity	Increase: skull defect Decrease: focal injury or extra- axial collection	Post-craniotomy Subdural haematoma	
Triphasic waves, occurring periodically	Diffuse encephalopathy, usually metabolic	Hepatic encephalopathy Uraemic encephalopathy	
Periodic lateralized epileptiform discharges (PLEDs): sharp- wave-slow- wave complexes occurring periodically	Acute focal cerebral injury	Stroke Herpes simplex encephalitis	

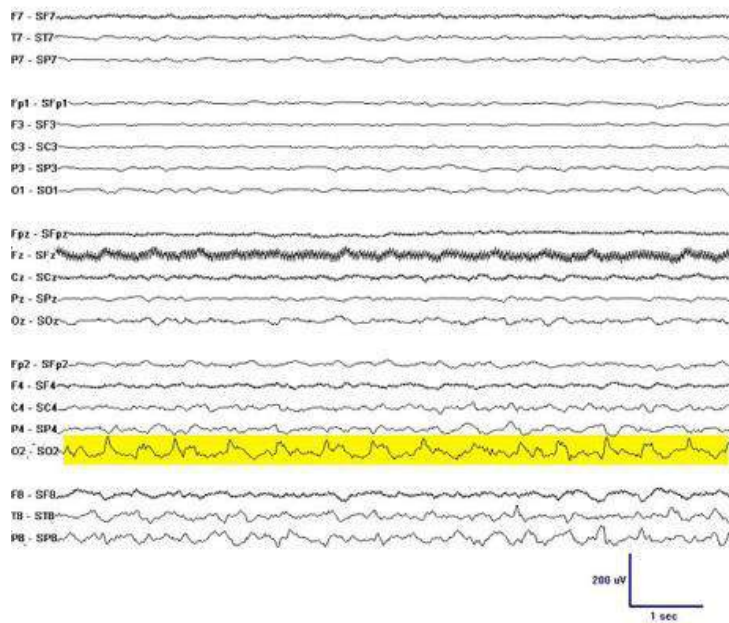
EEG abnormalities

Burst-suppression EEG pattern



Bursts of high-amplitude sharp activity with intervening suppression (non-standard montage, channels not labelled)

PLEDs



These are most clearly seen in channel O2-SO2 (highlighted) - periodic sharply contoured waveforms occur at 1-1.5 Hz

Intracranial pressure monitoring

Intracranial pressure monitoring utilising parenchymal or intraventricular transducers is commonly encountered in ICUs. The ICP waveform may provide qualitative as well as quantitative information about the brain.

P3 = Dicrotic wave

ICP waveform abnormalities

Waveform characteristic	Significance
'A' waves or plateau waves: high amplitude waves of 50-100mmHg sustained for up to 15 minutes	Raised ICP with compromised cerebral blood flow
'B' waves:"saw-tooth" appearance with small changes in pressure every 0.5-2 minutes	Poor intracranial compliance
'C' waves: low amplitude oscillations up to 20mmHg for approximately 1 minute with a frequency of approximately 5 per minute	May be normal Associated with variations in vasomotor tone
Flat ICP trace	Damped trace from blockage of an intraventricular catheter or compression or kinking of the transducer

Elevated P2 with a rounded appearance of the waveform. The three distinct parts of each waveform are lost.	Raised ICP
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Cardiotocography

CTG overview

Patients with obstetric emergencies may require intensive care management. Cardiotocographs (CTGs) are routinely performed to assess foetal wellbeing.

Early decelerations: reflex bradycardia occurs at the start of contractions with head compression. The foetal heart rate returns to baseline after the contraction - seen with normal labour

Late decelerations: delayed fall in foetal heart rate after the contraction begins which returns to the baseline well after the contraction ends, seen with foetal hypoxia

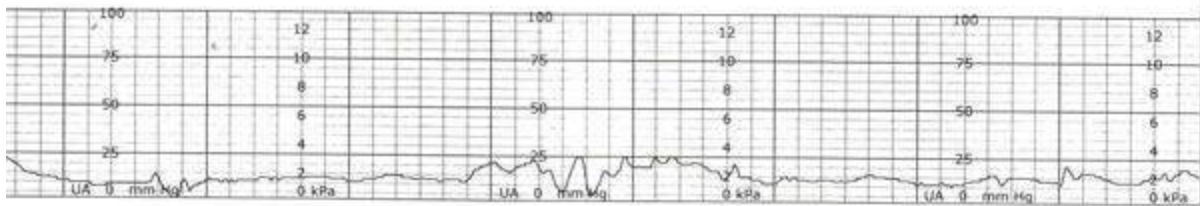
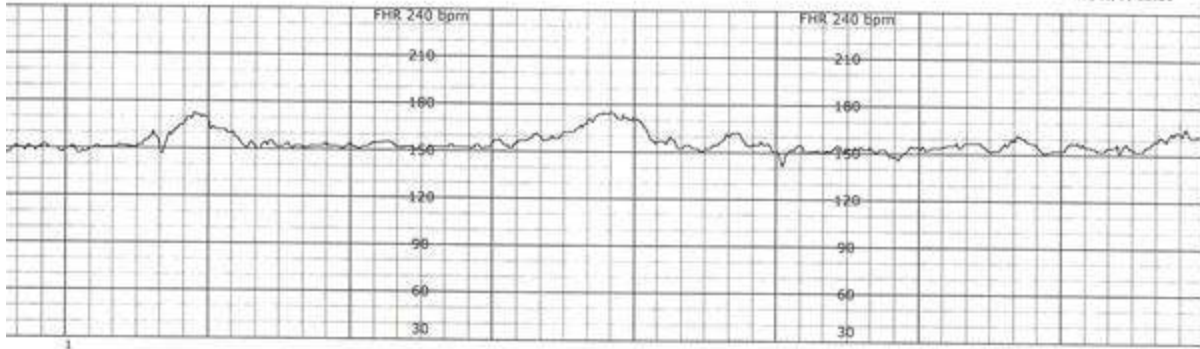
Variable decelerations: decelerations occur at variable times during the contraction. These are normal and healthy. Decreased variability is seen with hypoxia, sleep and maternal sedatives

Accelerations: the normal basal foetal heart rate is 120-160 beats per minute with small, rapid, rhythmic fluctuations. The increase in rate is usually 5-15 beats per minute

CTG patterns

Normal reactive CTG

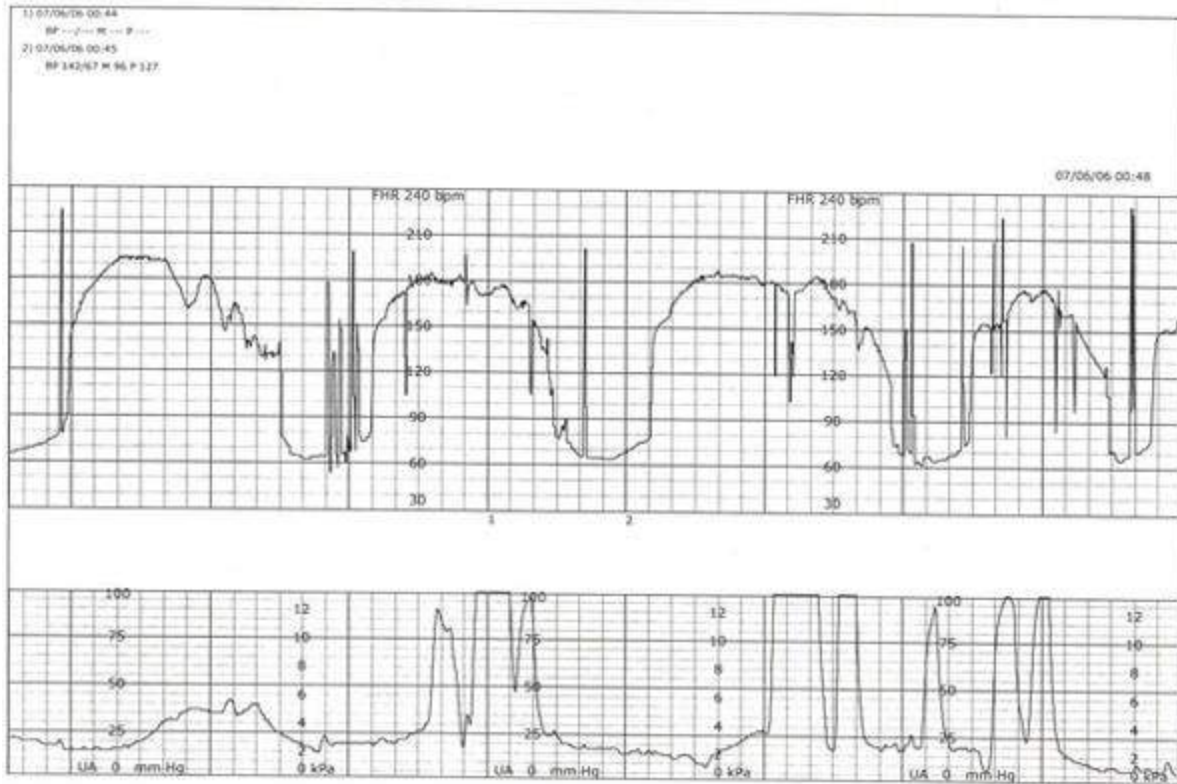
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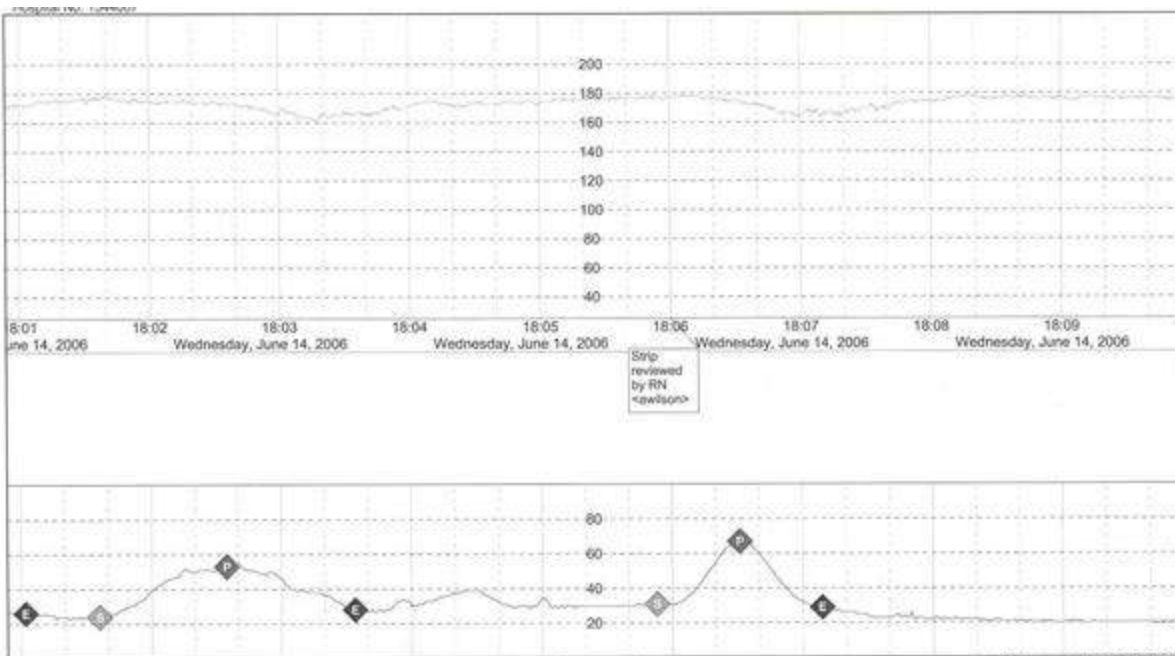
Reassuring CTG with contractions

The figure consists of two panels. The top panel displays two time-series plots. The left plot shows FHR (bpm) on the y-axis (30 to 210) against time. The right plot shows IAP (mmHg/kPa) on the y-axis (0 to 12) against time. The bottom panel displays three time-series plots. The left plot shows 1740 external INOP INOP TOCO (mmHg/kPa) on the y-axis (0 to 100) against time. The middle plot shows IAP (mmHg/kPa) on the y-axis (0 to 12) against time. The right plot shows IAP (mmHg/kPa) on the y-axis (0 to 12) against time.

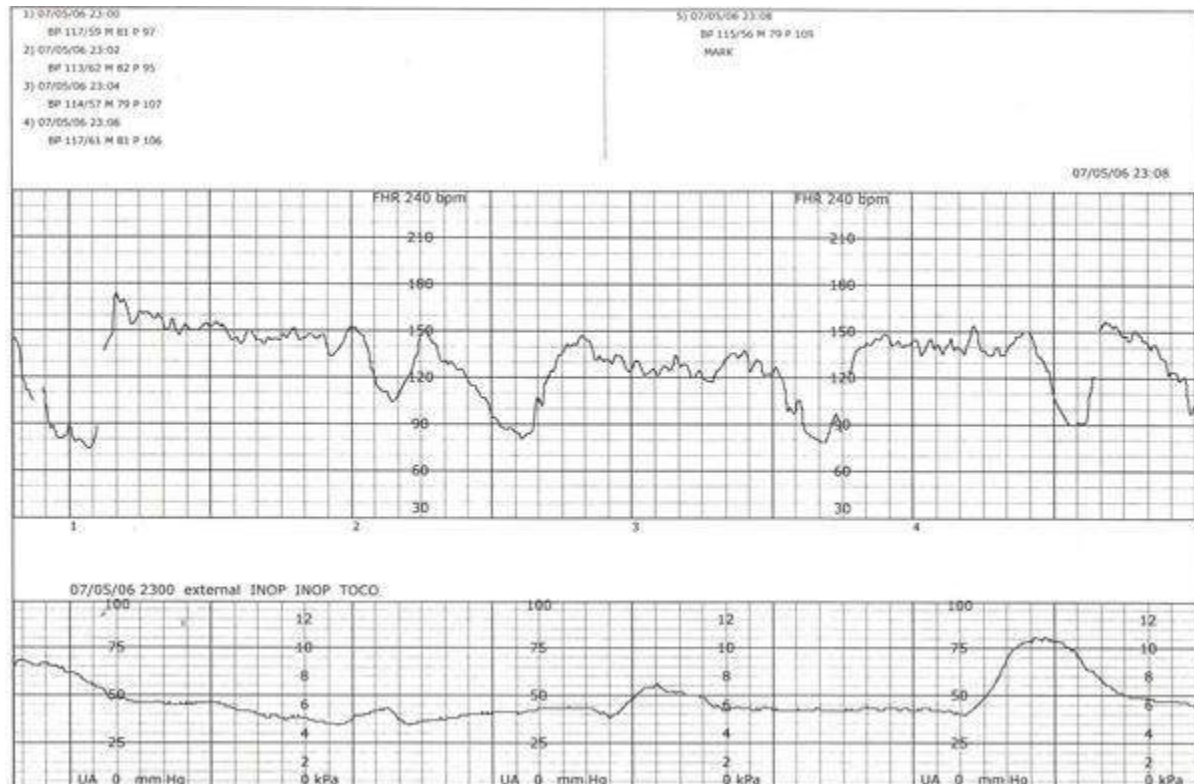
Severe variable decelerations



Subtle late decelerations



Variable decelerations



CRITICAL CARE LETRUTURE

Airway management

Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. Anaesthesia. 2004; 59: 675–94.

Methods

The guidelines presented in this paper are a result of discussions among members of the Difficult Airway Society in the United Kingdom. The basis behind them is that problems with tracheal intubation are the leading cause of hypoxic anaesthetic death and brain injury. Emphasis is given to maintaining oxygenation, along with airway planning pre-intubation.

Findings

Easy-to-use separate flow charts were developed for: i) unanticipated difficult tracheal intubation during routine induction of anaesthesia in an adult patient; ii) unanticipated difficult tracheal intubation during rapid sequence induction of anaesthesia (with suxamethonium) in a non-obstetric patient; and iii) failed intubation, increasing hypoxaemia, and difficult ventilation in the paralysed, anaesthetised patient – the 'can't intubate, can't ventilate' situation.

Significance

Various guidelines exist for the management of the difficult airway. Those presented in this paper are easy to follow and applicable in a wide variety of situations, providing a solid basis for airway planning. Alternatively, the American Society of Anesthesiologists (ASA) Guidelines are also widely used. These can be accessed at www2.asahq.org

Heard AM, Green RJ, Eakins P. The formulation and introduction of a 'can't intubate, can't ventilate' algorithm into clinical practice. *Anaesthesia*. 2009; 64: 601–8.

Methods

This paper describes the introduction of a 'can't intubate, can't ventilate' algorithm into a department. It involves the use of a manikin and then animal model, with practice of different techniques of achieving a surgical airway.

Findings

The study evaluated 10 participants on success and time to ventilation. The authors produced an algorithm suggesting initial use of cannula cricothyroidotomy or tracheotomy because of familiarity of anaesthetists with cannulae and their easy availability. Subsequent establishment of an airway to allow oxygenation and ventilation is discussed.

Significance

As no prospective trial can be readily performed in this area further suggestions on how to proceed in this difficult situation are a welcome addition to rescue airway management. In addition, the best way to ensure critical care doctors can learn these essential skills is the subject of much debate. In the age of multimedia, video modelling may be integrated into the guidelines and various forms of simulation used to prepare doctors prior to their being challenged in real life.

Pott LM, Murray WB. Review of video laryngoscopy and rigid fiberoptic laryngoscopy. *Current Opinion in Anaesthesiology*. 2008; 21: 750–8.

Methods

Video laryngoscopy and rigid fibre-optic laryngoscopy are new aids to intubation. These devices provide indirect views compared to the traditional Macintosh blade, where the cords are visualised directly. The video laryngoscopes have either built-in or stand-alone screens. Images may also be transmitted to monitors by fibre-optic bundles or a prism system.

Findings

Although the new devices can provide excellent views of the glottic opening, problems can still be encountered in achieving intubation. Some of these devices come with rigid stylets to railroad the tracheal tube over and others with a channel to direct the tracheal tube.

Significance

Video laryngoscopy increases the armoury of equipment to achieve successful intubation in the elective or emergency situation. Studies have indicated a relatively quick learning curve with these devices. New devices must be carefully evaluated and their role in clinical practice elucidated.

Campos JH, Hallam EA, Van Natta T, Kernstine KH. Devices for lung isolation used by anesthesiologists with limited thoracic experience: comparison of double-lumen endotracheal Tube, Univent® torque control blocker, and Arndt wire-guided endobronchial blocker®. *Anesthesiology*. 2006; 104: 261–6.

Methods

This prospective, randomised trial compared time to position, and accuracy of position with different lung isolating techniques using double-lumen tubes and bronchial blockers.

Findings

There was no significant difference in time to position, but failure rate of positioning was between 36% and 39%, with no difference between the devices used.

Significance

Bronchial anatomy knowledge was felt to be the key determinant in successful placement of the lung-isolating device. Temporary lung isolation in the intensive care unit for pulmonary haemorrhage or differential lung ventilation may require the use of one of these devices. Campos has written extensively on this topic and more recently has looked at lung isolation techniques for patients with difficult airways. Although there are no large studies to support this recommendation, in this setting a bronchial blocker or insertion of a double-lumen tube (substituted for a standard tube over an airway catheter exchange device) is recommended (Campos JH. Lung isolation techniques for patients with a difficult airway. *Current Opinions in Anesthesiology*. 2010; 23: 12–17).

Fan T, Wang G, Mao B, et al. Prophylactic administration of parenteral steroids for preventing airway complications after extubation in adults: meta-analysis of randomised placebo controlled trials. *BMJ*. 2008; 337: 1088–91.

Methods

Systematic review with meta-analysis of six trials involving 1923 patients evaluating the effects of steroids on the incidence of laryngeal oedema and re-intubation rates.

Findings

Steroid administration significantly decreased the risk of laryngeal oedema and the need for re-intubation (reduced by 71%). There was heterogeneity in the timing, doses and choice of steroid, but it is concluded that with a multiple dose regimen that there is a number needed to treat of only 5.

Significance

This is likely to be applicable to only a small number of ICU patients as laryngeal oedema is only one cause of failed extubation. There remain ongoing concerns about side effects, particularly with high, repeated doses. A study evaluating the efficacy in patients at high risk of laryngeal oedema (e.g. prolonged intubation or absence of a cuff leak) is needed

Anaesthesia

Myles PS, Leslie K, Chan MT, et al. (ENIGMA Trial Group). Avoidance of nitrous oxide for patients undergoing major surgery: a randomized controlled trial. *Anesthesiology*. 2007; 107: 221–31.

Method

Patients were randomised into two groups: a nitrous oxide-free (80% oxygen and 20% nitrogen) and nitrous oxide-based (70% nitrous oxide and 30% oxygen) anaesthetic. The primary end-point was duration of hospital stay and secondary end-points, such as postoperative nausea and vomiting, pneumonia, wound infections and myocardial infarction, were recorded.

Findings

The study recruited 2050 patients. There was no difference in length of stay, but a significant increase in the secondary end-points with nitrous oxide. The study concluded that routine use of nitrous oxide should be questioned in view of the positive findings in this study.

Significance

Nitrous oxide has been commonly used in anaesthetic practice for many years, but has known effects on vitamin B

and folate metabolism. It limits the use of high-inspired oxygen concentrations and is not commonly used in cardiac or neuro anaesthetic practice. (The IHAST group has stated there is 'no evidence for its unconditional avoidance in patients at risk of cerebral ischaemia'; Pasternak JJ, McGregor DG, Lanier WL, et al. Effect of nitrous oxide on long-term neurologic and neuropsychological outcome in patients who received temporary proximal artery occlusion during cerebral aneurysm clipping surgery. *Anesthesiology*. 2009; 110: 563–73). The investigators have commenced ENIGMA II, a large, multicentre, randomised trial looking at the effects of nitrous oxide in patients with moderate and high-risk coronary heart disease undergoing major surgery. Primary end-points are death and cardiovascular events. Plans are to recruit 7000 patients in order to find an absolute risk reduction of 2%.

Lee C, Jahr JS, Candiotti KA, Warriner B, Zornow MH, Naguib M. Reversal of profound neuromuscular block by sugammadex administered three minutes after rocuronium: a comparison with spontaneous recovery from succinylcholine. *Anesthesiology*. 2009; 110: 1020–5.

Methods

Randomised study of 115 ASA class 1–2 patients who received either rocuronium (1.2 mg/kg), followed by sugammadex (16 mg/kg) or suxamethonium (1 mg/kg). Sugammadex was administered 3 minutes after the rocuronium with neuromuscular function monitored with acceleromyography.

Findings

Mean time of recovery to T1 (first twitch of train of four) was significantly quicker than with spontaneous recovery with suxamethonium.

Significance

Sugammadex is a new drug in anaesthetic practice that has a role in conjunction with rocuronium when suxamethonium is contraindicated (e.g. burns and spinal cord injured patients). This drug development, along with many reports in the literature of difficult assessment, poor/absent monitoring of the neuromuscular junction, may help with the prevention and management of unrecognised residual neuromuscular blockade. (*Anaesthesia*. 2009; 64: s1: 1–89).

Haynes AB, Weiser TG, Berry WR, et al. (Safe Surgery Saves Lives Study Group). A surgical safety checklist to reduce morbidity and mortality in a global population. *New England Journal of Medicine*. 2009; 360: 491–9.

Methods

The study enrolled 7688 patients from eight hospitals across the world. Data was prospectively collected on non-cardiac surgical patients, looking at clinical processes and outcomes (n = 3733). The safe surgery checklist (based on the WHO guidelines for safe surgery) was introduced and data was collected on this group (n = 3955).

Findings

The overall death rate was 1.5% before introducing the safe surgery checklist and afterwards was significantly different at 0.8%. The rate of any complication dropped from 11% to 7% after checklist introduction.

Significance

This study reveals a reduction in death rates and complications with the introduction of the checklist described in the article. The checklist involves a 'sign-in' before anaesthesia is commenced, a 'time-out' before the incision is made and a 'sign-out' before the patient leaves the operating room. The authors describe limitations of the study, but state no significant surgical delays brought about by its introduction. The results were applicable across high- and low-

economic sites. The group is also introducing the 'global pulse oximetry concept' campaign, mainly for anaesthesia in countries in the developing world. See www.who.int/patientsafety/safesurgery/pulse_oximetry.

Avidan MS, Zhang L, Burnside BA, et al. Anesthesia awareness and the bispectral index. *New England Journal of Medicine*. 2008; 358: 1097–108.

Methods

The B-unaware study was a randomised trial involving 2000 patients who were assigned to a BIS (bispectral index) group or eTAG (end tidal anaesthetic gas) group. They were assigned ranges of 40–60 and 0.7–1.3 MAC (minimum alveolar concentration) respectively. Awareness was assessed at 24 hours, 24–72 hours and at 30 days.

Findings

There were two definite cases of awareness in each group. The BIS value was greater than 60 in one of the cases and the eTAG was less than 0.7 MAC in three cases. There was no significant difference in eTAG in both groups. They were unable to support the use of BIS monitoring as a standard.

Significance

The incidence of awareness under anaesthesia is reported as between 0.1 and 0.2 per 100 patients. The utility of BIS monitoring remains unclear. This study was not able to reproduce the results of previous studies, such as the B-aware trial which involved 2463 patients. This double-blind multicentre trial found an 82% reduction in awareness using BIS (Myles PS, Leslie K, McNeil J, Forbes A, Chan MT. Bispectral index monitoring to prevent awareness during anaesthesia: the B-Aware randomised controlled trial. *Lancet* 2004; 363: 1757–63). The authors state that awareness occurred even in the target range, suggesting that the unknown mechanisms of action of anaesthetic agents makes targeting to single variables inappropriate. Also, delayed reporting of awareness was apparent, which the anaesthetic team may miss. The patients in different studies were also of differing levels of risk. The jury is still out on BIS.

Dewachter P, Mouton-Faivre C, Emala CW. Anaphylaxis and anesthesia: controversies and new insights. *Anesthesiology*. 2009; 111: 1141–50.

Methods

This review article covers new definitions and pathophysiology of allergic reactions related to anaesthesia. The incidence is stated to be between 1 in 10,000–20,000 procedures and specifically 1 in 6500 doses of neuromuscular blocking agent. A clinical severity scale is presented, with discussion of differential diagnosis and investigation. Suspect agents, including latex, dyes, antiseptics and antibiotics are discussed.

Findings

Treatment emphasises the use of basic life support, fluids and epinephrine (dosing of which is matched with the clinical grade).

Significance

This review updates and summarises current thinking on anaphylaxis relevant to anaesthetic practice. Guidelines are available from the AAGBI at www.aagbi.org.

Ali SZ, Taguchi H, Rosenberg H. Malignant hyperthermia. *Best Practice and Research Clinical Anaesthesiology*. 2003; 17: 519–33.

Method

This review article discusses the pathophysiology, clinical features and management of malignant hyperthermia.

Findings

Although it is an uncommon condition (1 in 50,000–150,000 adult anaesthetics), it is a life-threatening (70% mortality if untreated), inherited (autosomal dominant) pharmacogenetic disorder.

Significance

Malignant hyperthermia now has a mortality of less than 5% when treated appropriately. Triggering agents include suxamethonium and volatile anaesthetic agents that are in common clinical practice. Treatment with dantrolene and its dosing is presented. Guidelines are available from the AAGBI at www.aagbi.org or Malignant Hyperthermia Australia and New Zealand (MHANZ) at www.anaesthesia.mh.org.au/contact-us-links/w1/i1002695

Cardiovascular medicine - Acute Coronary Syndromes

Results

At 6 months there was a significant reduction in neo-intimal proliferation and degree of stent stenosis in the sirolimus group as well as a significant reduction in major cardiac events at 1 year.

Significance

This study was the first of any of its kind to look at substances (e.g. sirolimus, paclitaxel) that inhibit thrombotic, inflammatory and/or proliferative processes that may reduce coronary artery stent stenosis and occlusion when eluted. Several systematic reviews were subsequently completed that show encouraging mid-term superiority of drug-eluting stents (DES) over bare metal stents (BMS) in terms of re-stenosis and adverse cardiac events. Enthusiasm for DES has been tempered by risks of stent thrombosis and a need for prolonged dual antiplatelet therapy (aspirin and clopidogrel). Recent ACC/AHA Guidelines recommend a minimum of 3 months of these drugs for sirolimus, and 6 months for paclitaxel-eluting stents. More holistic issues, such as the individual risk of bleeding, the need for invasive procedures and likely compliance, have become important considerations for interventionalists.

Based on their recent literature review and financial modelling, the UK NHS NICE Guidelines recommend a DES for narrow (<3 mm calibre) or long (>15 mm) target lesions or where there is no more than a ≤300 price difference of the DES over the BMS. Cost effectiveness has joined efficacy, quality and safety as the fourth criteria for evaluating new drugs and technologies in healthcare. Biodegradable and bioabsorbable stents are also on the horizon. Studies evaluating stent superiority for specific pathologies (e.g. saphenous vein graft stenosis) are ongoing

Cardiovascular medicine - Heart failure

Cotter G, Metzko E, Kaluski E, et al. Randomised trial of high-dose isosorbide dinitrate plus low-dose furosemide versus high-dose furosemide plus low-dose isosorbide dinitrate in severe pulmonary oedema. Lancet. 1998; 351: 389–93.

Methods

Randomised study of 110 patients with acute pulmonary oedema presenting with oxygen saturations below 90% who all received high-flow oxygen, intravenous (IV) furosemide 40 mg and morphine 3 mg, then either isosorbide mononitrate (3 mg IV boluses every 5 minutes) or furosemide (80 mg IV boluses every 15 minutes plus isosorbide mononitrate 1 mg/hr).

Findings

Low-dose furosemide and high-dose nitrates were significantly more effective in reducing the need for mechanical ventilation and the frequency of myocardial infarction.

Significance

This study helped define the relative role of two agents that had become the mainstay of therapy for acute pulmonary oedema and had theoretical risks and benefits at different doses. Few additional agents have challenged the role of nitrates in this setting. Of these, the most debated is nesiritide, the recombinant B-type natriuretic peptide, which has natriuretic, diuretic and vasodilator properties. The most well-known study was by the VMAC investigators that compared IV nesiritide to nitroglycerin (Intravenous nesiritide vs. nitroglycerin for treatment of decompensated congestive heart failure: a randomized controlled trial. *JAMA*. 2002; 287: 1531–40). Although this demonstrated improvement in haemodynamics and symptoms, subsequent studies raised concerns about increased renal failure and mortality.

Follath F, Cleland JG, Papp JG, et al. Efficacy and safety of intravenous levosimendan compared with dobutamine in severe, decompensated low-output heart failure (the LIDO study): a randomised double-blind trial. *Lancet*. 2002; 360: 196–202.

Methods

Multicentre, randomised, controlled, double-blind trial involving 203 patients with low-output heart failure. Patients received the calcium sensitizer and vasodilator levosimendan (loading dose of 24 mcg/kg over 10 min, then a continuous infusion of 0.1 mcg/kg/min for 24 hours) or dobutamine (5 mcg/kg/min, increased to 10 mcg/kg/min if an inadequate response at 2 hours).

Results

Significantly more patients in the levosimendan group had an increase of at least 30% in cardiac output and at least a 25% reduction in pulmonary–capillary wedge pressure. There was also a significant reduction in 6-month mortality in the levosimendan group.

Significance

This was the first of a number of similar studies (RUSSLAN, CASINO, REVIVE 1/2 and SURVIVE). Results have been conflicting, with subsequent larger studies suggesting early haemodynamic improvements but no difference in long-term outcome compared to dobutamine. A possible role may be defined in the future (e.g. patients who decompensate on beta-blocker therapy for chronic heart failure or in cardiac surgery). There is no strong evidence supporting routine inotrope therapy (including phosphodiesterase inhibitors such as milrinone or beta-adrenergic agents) for patients with acute decompensated heart failure.

Packer M, Bristow MR, Cohn JN, et al. The effect of carvedilol on morbidity and mortality in patients with chronic heart failure. US Carvedilol Heart Failure Study Group. *New England Journal of Medicine*. 1996; 334: 1349–55.

Methods

Randomised, double-blind, placebo controlled study of 1094 patients with chronic heart failure with LVEF <35% received carvedilol or placebo. This was on a background of digoxin, diuretics and an ACE inhibitor.

Results

A significant reduction in the risk of death was seen in the carvedilol group.

Significance

This study has been followed by a number of large, high-quality, randomised controlled studies, with significant data accumulating favouring carvedilol, metoprolol and bisoprolol in patients with all classes of heart failure, including those with very low ejection fractions. Within a decade, traditional attitudes about these agents have been challenged, and patients previously considered to have contraindications (e.g. diabetics, poor ejection fractions) are now experiencing considerable benefits. This is most likely due to a reduction in fatal arrhythmias rather than progression of pump dysfunction. In this setting, bisoprolol, a non-selective agent, may be superior to the more selective agent metoprolol (carvedilol or metoprolol European trial). It is also unclear whether it is more beneficial to maximise the dose of these agents over ACE inhibitors where blood pressure limits tolerance of both classes of drugs.

Pitt B, Zannad F, Remme WJ, et al. The effect of spironolactone on morbidity and mortality in patients with severe heart failure. Randomized Aldactone Evaluation Study (RALES) Investigators. New England Journal of Medicine. 1999; 341: 709–17.

Methods

Randomised, double-blind controlled trial that included 822 patients with severe heart failure and a LVEF $\leq 35\%$, who were already receiving an ACE inhibitor, loop diuretic and in most cases digoxin. Patients were given spironolactone (25 mg orally daily) or placebo.

Results

There was a significant 30% reduction in mortality in the spironolactone group, as well as a reduction in symptoms and hospital admissions for worsening heart failure. There was a significant increase in the incidence of gynaecomastia or breast pain in men who received spironolactone.

Significance

The RALES study did not identify hyperkalaemia as a significant problem. Subsequent studies, however, have shown higher rates of hyperkalaemia with serious adverse events culminating in death. The addition of spironolactone to heart failure management should therefore be accompanied by close monitoring of renal function and serum electrolytes.

The SOLVD Investigators. Effect of enalapril on mortality and the development of heart failure in asymptomatic patients with reduced left ventricular ejection fractions. New England Journal of Medicine. 1992; 327: 685–91.

Methods

Randomised, placebo controlled study of 4228 patients with heart failure with a LVEF of $\leq 35\%$ or less. Subjects received enalapril (2.5–20 mg daily) or placebo.

Results

Enalapril reduced the incidence of symptomatic heart failure and related hospitalisations, with a trend to fewer deaths due to cardiovascular causes. A reduction in mortality was later reported in patients with symptomatic heart failure who received enalapril. A 12-year follow-up study found significant improvements in mortality for patients with both asymptomatic and symptomatic heart failure who received 3–4 years of enalapril.

Significance

The SOLVD study was one of the early studies that helped to clarify the role of ACE inhibitors in clinical practice. A

plethora of evidence exists, confirming a role for a number of these agents with a broad range of beneficial effects – treatment of heart failure, reduction in cardiac events in coronary artery disease, prevention of stroke, management of chronic hypertension, prevention and management of diabetic nephropathy. The addition of an angiotensin receptor blocker (e.g. candesartan) to an ACE inhibitor may confer additional benefits in heart failure (CHARM Investigators and Committees. *Lancet*. 2003; 362: 759–66), but their major role is as an effective alternative to those intolerant of ACE inhibitors.

Cohn JN, Archibald DG, Ziesche S, et al. Effect of vasodilator therapy on mortality in chronic congestive heart failure. Results of a Veterans Administration Cooperative Study. *New England Journal of Medicine*. 1986; 314: 1547–52.

Methods

Randomised, double-blind trial of 642 men with impaired cardiac function and reduced exercise tolerance who were taking digoxin and a diuretic to receive additional treatment with placebo, prazosin (20 mg/day), or the combination of hydralazine (300 mg/day) and isosorbide dinitrate (160 mg/day).

Findings

The group that received hydralazine and isosorbide dinitrate had a significant rise in LVEF at 8 weeks and at 1 year, and a reduced mortality.

Significance

This study was in the pre-ACE inhibitor era, but remains the basis of recommendations that nitrates and hydralazine may be beneficial alternatives in patients intolerant of ACE inhibitors or ARBs. In the black population with heart failure, a mortality benefit from the addition of these agents to ACE inhibitors and beta-blockers has been demonstrated (Taylor AL, Ziesche S, Yancy C, et al. Combination of isosorbide dinitrate and hydralazine in blacks with heart failure. *New England Journal of Medicine*. 2004; 351: 2049–57).

The Digitalis Investigation Group. The effect of digoxin on mortality and morbidity in patients with heart failure. *New England Journal of Medicine*. 1997; 336: 525–33.

Methods

Randomised trial involving 6800 patients with a LVEF $\leq 45\%$. In addition to diuretics and ACE inhibitors they received either 0.25 mg/day of digoxin or placebo.

Results

No difference in mortality, but a significant reduction in hospital admissions was seen with digoxin.

Significance

An ancillary trial involving 988 patients with an LVEF $>45\%$ showed no difference in the combined outcome of death or hospitalisation due to worsening heart failure. Other studies have raised the possibility of a dose-related increase in mortality if high serum levels are achieved, which is not seen with low levels. Beneficial effects may be seen with low levels related to attenuation of sympathetic activation and neurohumoral alterations, but for a drug without a mortality benefit the significant risks must be carefully weighed against the benefits.

The Antiarrhythmics versus Implantable Defibrillators (AVID) Investigators. A comparison of antiarrhythmic-drug therapy with implantable defibrillators in patients resuscitated from near-fatal ventricular arrhythmias. *New England Journal of Medicine*. 1997; 337: 1576–83.

Methods

Randomised trial of implantable cardioverter-defibrillators (ICD) and class III antiarrhythmics (predominantly amiodarone), involving 1016 patients in patients resuscitated from near-fatal ventricular fibrillation or cardioversion after sustained ventricular tachycardia (who also had a LVEF $\leq 40\%$ and syncope or other serious cardiac symptoms).

Findings

A significant reduction in mortality was seen in the group who received an ICD.

Significance

Several studies have confirmed this mortality benefit. Antiarrhythmic drugs, however, are still often required in patients with an ICD, for the management of atrial tachyarrhythmias and prevention of ICD shocks. Currently, the ACC/AHA Guidelines recommend ICDs as primary prevention to reduce mortality from sudden death in patients with non-ischaemic cardiomyopathy with an LVEF $\leq 30\%$ with symptoms on optimal chronic medical therapy with a reasonable expectation of good functional status for more than a year, or ischaemic heart disease at least 40 days post MI with the same additional criteria. They are also recommended as secondary prevention in patients with current or prior symptoms of heart failure and reduced LVEF with a history of cardiac arrest, VF or haemodynamically unstable VT.

Abraham WT, Fisher WG, Smith AL, et al. Cardiac resynchronization in chronic heart failure. New England Journal of Medicine. 2002; 346: 1845–53.

Methods

Randomised study of 453 patients with moderate-to-severe heart failure and an LVEF $\leq 35\%$ and QRS of at least 130 msec to atrial-synchronised biventricular pacing or a control group as an adjunctive therapy.

Results

The resynchronisation group had improved functional class, 6-minute walk distance, exercise time on a treadmill and LVEF with reduced hospitalisations for heart failure. Implantation was complicated by two deaths from asystole and two perforations of the coronary sinus requiring pericardiocentesis.

Significance

This intervention is increasingly being offered. There is a need for sinus rhythm and a reported learning curve exists. Many of these patients also meet the criteria for an implantable defibrillator.

Rose EA, Gelijns AC, Moskowitz AJ, et al. (REMATCH Study Group). Long-term use of a left ventricular assist device for end-stage heart failure. New England Journal of Medicine. 2001; 345: 1435–43.

Methods

Randomised study of 129 patients with end-stage heart failure and severe symptoms, ineligible for cardiac transplantation to a left ventricular assist device or ongoing optimal medical management.

Findings

A 48% reduction in the risk of death from any cause in the group that received left ventricular assist devices with a 52% 1-year and 23% 2-year survival rate. Quality of life was also significantly better at 1 year in the device group.

Significance

This study supported the role of devices as so-called 'destination therapy'. The costs of such devices is substantial

and the significance of long-term side effects, including driveline infections, are still being elucidated. In some countries, including Australia and the UK, the emphasis remains on focusing mechanical support programs and scarce resources on younger patients requiring a bridge to transplantation or recovery. Sponsored studies, however, evaluating a range of devices (including biventricular assist devices) in different patient circumstances, are ongoing.

Conzano MR, Guglin ME, Saltzberg MT, et al. (UNLOAD Trial Investigators). Ultrafiltration versus intravenous diuretics for patients hospitalized for acute decompensated heart failure. 2007; 49: 675–83.

Methods

Randomised trial of 200 patients hospitalised with heart failure, LVEF $\leq 40\%$ with at least two signs of hypervolaemia received either veno-venous ultrafiltration (coined 'aquapheresis') or intravenous diuretics.

Findings

The ultrafiltration group had greater weight and net fluid loss at 48 hours and fewer rehospitalisations and unscheduled visits with heart failure within 90 days with no significant difference in serum creatinine or mortality.

Significance

The benefits demonstrated may be due to the greater capacity for sodium to be removed than with diuretics, as there was a disconnect between the amount of fluid removed and the outcomes. This study used the Aquadex System 100™ (CHF Solutions, Minneapolis, Minnesota). This system utilises peripheral (e.g. CHF 6Fr dual lumen peripheral extended length cannula (ELC), a 5Fr single lumen peripheral ELC and an 18G IV) or a 7–8Fr dual-lumen central venous catheter. Average fluid removal rates of 250 mL/hr are described and anticoagulation with heparin (APTT at least twice normal) is recommended. It is unclear whether this resource-intensive strategy is truly cost effective or will become widespread. Heart failure is a growing problem and interventions using conventional renal replacement equipment are also likely to be explored.

Cardiovascular medicine - Surgery

EVAR trial participants. Endovascular aneurysm repair versus open repair in patients with abdominal aortic aneurysm (EVAR trial 1): randomised controlled trial. Lancet. 2005; 365: 2179–86.

Methods

Multicentre, randomised controlled trial of 1082 patients aged over 60 years with abdominal aortic aneurysms of at least 5.5 cm diameter referred for elective repair. Patients either received endovascular aneurysm repair (EVAR) or traditional open repair.

Findings

There was no difference in all-cause mortality at 4 years, although there was a reduction in aneurysm-related deaths. There was an increase in complications and re-interventions with EVAR, which was also significantly more expensive.

Significance

The initial study report (Lancet 2004) showed an impressive reduction in 30-day mortality with EVAR with reduced hospital length of stay. This finding has been confirmed by other subsequent studies. The EVAR 2 study reported results of a further study period (8 years) and found a lower aneurysm related mortality compared with no repair (New England Journal of Medicine. 2010; 362: 1872–80).

Endovascular management of thoracic and lumbar aortic aneurysms continues to develop, with increasingly complex stenting procedures with fenestration of major branches. These procedures are enabling treatment for previously inoperable patients and offering poor surgical candidates a definitive treatment option.

It remains to be seen if there is equipoise of open versus endovascular repair of patients with ruptured aneurysms, although there are series that show for haemodynamically stable patients with favourable anatomy EVAR is an excellent option, particularly in high-risk patients. The multicentre randomised UK IMPROVE study will attempt to answer this question.

Khan NE, de Souza A, Mister R, et al. A randomised comparison of off-pump and on-pump multivessel coronary-artery bypass surgery. *New England Journal of Medicine*. 2004; 350: 21–8..

Methods

Single-centre, randomised, controlled study comparing CABG performed 'on' versus 'off' pump followed by coronary angiography at 3 months.

Findings

Patients in both groups received a mean of three grafts each and none died. There was a significant increase in graft patency at 3 months for the on-pump group.

Significance

Despite several promising case series favouring off-pump grafting with a range of benefits in terms of reduced morbidity, randomised trials such as this early one were less convincing. A systematic review comparing both techniques found a significant reduction in risk of atrial fibrillation, but an effect on mortality, myocardial infarction, stroke and graft patency was less clear (Moller CH, Penninga L, Wetterslev J, et al. *European Heart Journal*. 2008; 29: 2601–16).

Fergusson DA, Hebert PC, Mazer CD, et al. (BART Investigators). A comparison of aprotinin and lysine analogues in high-risk cardiac surgery. *New England Journal of Medicine*. 2008; 358: 2319–31.

Methods

The antifibrinolytic aprotinin was compared to either tranexamic acid or aminocaproic acid in determining which was superior in decreasing massive postoperative bleeding and other important clinical consequences. High-risk cardiac surgical patients (2331) were randomly assigned to one of the three drug groups. Primary outcome was massive postoperative bleeding; secondary outcome included death at 30 days.

Findings

Early termination of the trial occurred due to a higher rate of death detected in the patients receiving aprotinin. The relative risk of death in the aprotinin group as compared to that in both groups receiving lysine analogues was 1.53.

Significance

The use of aprotinin was previously shown to reduce bleeding in cardiac surgery and had supportive meta-analyses. This more robust study, however, was able to show a difference in mortality despite a reduction in blood loss (hence blood transfusion). This is probably due to broader effects of the non-specific serine protease inhibitor. Bayer, the drug's producer, was shrouded in scandal with allegations it suppressed data raising serious concerns about this drug's side effects for many years. Aprotinin has fallen out of favour. Instead, tranexamic acid has gained popularity, although the optimal dosing schedule is unclear and studies of low versus high dose are ongoing. The

situation is complex, as a number of factors have been associated with morbidity after cardiac surgery. For example, the need for packed cell transfusion, particularly of packed cells older than 2 weeks (Adamson JW. New blood, old blood, or no blood? *New England Journal of Medicine*. 2008; 358: 1295–6).

Ethics

Sprung CL, Cohen SL, Sjokvist P, et al. Ethicus Study Group. End-of-life practices in European intensive care units: the Ethicus Study. *JAMA*. 2003; 290: 790–7.

Methods

Prospective, observational study of 37 European ICUs in 17 countries of frequencies and patterns of end-of-life care regarding 31,417 consecutive patients.

Findings

There were 4248 patients who died or had a limitation of life-sustaining therapy. Active shortening of the dying process was reported in seven countries. However, there was substantial intercountry variability; factors associated with limiting versus continuation of life-sustaining therapy were patient age, acute and chronic diagnoses, number of days in ICU, region and religion. It was also noted that although shortening of the dying process was rare, clarity between withdrawing therapies and shortening of the dying process and between therapies intended to relieve pain and suffering and those intended to shorten the dying process may be lacking.

Significance

This is an area of much debate. As an ageing population, with high expectations of what intensive care medicine can offer, stretches ICU resources, this study was timely. An understanding of the ICU triage decision-making process of intensivists, as well as their end-of-life practices, is a high research priority. It has been over a decade since the increasing trend towards withholding and withdrawing life support was described, with 90% of patients who die in ICU doing so after a decision to limit therapy (Prendergast TJ, Luce JM. Increasing incidence of withholding and withdrawal of life support from the critically ill. *American Journal of Respiratory and Critical Care Medicine*. 1997; 155: 15–20).

White DB, Evans LR, Bautista CA, Luce JM, Lo B. Are physicians' recommendations to limit life support beneficial or burdensome? *American Journal of Respiratory and Critical Care Medicine*. 2009; 180: 320–5.

Methods

Prospective, qualitative and quantitative study using 160 simulated ICU family conferences with surrogates of critically ill patients, comparing satisfaction with physician versus surrogate decision-making to withdraw life support.

Findings

There were approximately equal numbers favouring each option. Interestingly, approximately 50% of surrogates who preferred the physician to make the decision felt physician decision-making over end-of-life care was a natural part of their role, while 80% who felt the surrogate should make the decision felt it should not be part of the doctor's role.

Significance

This highlights the complexity of decision-making in end-of-life care and the lack of a 'one size fits all' approach. Informing and working with surrogates is a major challenge for intensivists and more work is needed to assist all

those engaged in this daily activity in order for the best outcomes and maximal satisfaction to be achieved for all involved in a patient's care.

Phillips RS, Wenger NS, Teno J, et al. Choices of seriously ill patients about cardiopulmonary resuscitation: correlates and outcomes. SUPPORT Investigators. Study to understand prognoses and preferences for outcomes and risks of treatments. American Journal of Medicine. 1996; 100: 128–37.

Methods

Cross-sectional evaluation of patient preferences regarding CPR and other treatments, quality of life, functional status, perceptions of prognosis and whether the patient had discussed CPR preferences with the physician.

Findings

There were 1995 eligible patients, of whom 84% were interviewed (7% in-hospital mortality, mean age 62 years). Of these, 28% did not want CPR. Diagnosis, being older, being more functionally impaired and a perception of a worse prognosis were associated with this decision. Only 29% had discussed this decision with their physician.

Significance

Patients need to be engaged in discussions regarding their end-of-life care. This is important if unwanted CPR and ICU admissions are to be avoided.

Schneiderman LJ, Gilmer T, Teetzel HD, et al. Effects of ethics consultations on nonbeneficial life-sustaining treatment in the intensive care setting: a randomized controlled trial. JAMA. 2003; 290: 1166–72.

Methods

Prospective, multicentre randomised controlled trial involving 551 patients for whom value-related treatment conflicts arose during the course of treatment in ICU. Patients either received an offer of ethics consultation or usual care.

Findings

There was no difference in mortality, although ethics consultations were significantly associated with reduced hospital and ICU length of stay, and days of ventilation in those who ultimately did not survive to discharge.

Significance

Ethics consultations may be helpful in resolving conflicts that may inappropriately prolong non-beneficial or unwanted treatments in ICU. Unfortunately, in many centres there are not the resources to fund such individuals. They also require specific training and experience that can be difficult to acquire. The most experience has developed in North America.

White DB, Katz MH, Luce JM, Lo, B. Who should receive life support during a public health emergency? Using ethical principles to improve allocation decisions. Annals of Internal Medicine. 2009; 150: 132–8.

Methods

Review of existing recommendations regarding public health emergencies, such as an influenza pandemic.

Findings

Existing recommendations reflect a utilitarian perspective where allocation is based on chances of survival to hospital discharge, but this risks denying certain patient groups potentially life-saving therapy (e.g. elderly and functionally impaired patients). An alternative approach of selections based on the maximum number of 'life-years' saved with

prioritisation of those who have had the least chance to survive through the life stages is discussed. The need to engage the public in discussions is explained.

Significance

These are complex issues and the application of the ethical principles to patients admitted to ICU should be under debate, not only for times of public health emergency but also in the current era where ICU care should be considered as a scarce resource.

Fluids and electrolytes - Glucose control

Malmberg K, Ryden L, Efendic S. et al. Randomized trial of insulin-glucose infusion followed by subcutaneous insulin treatment in diabetic patients with acute myocardial infarction (DIGAMI study): effects on mortality at 1 year. Journal of the American College of Cardiology. 1995; 26: 57–65.

Methods

Randomised study of 620 patients with acute myocardial infarction with a history of diabetes mellitus or a BSL elevated on presentation to an insulin–glucose infusion, followed by multidose subcutaneous insulin for at least 3 months or to a non-blinded control group.

Findings

An early significant reduction in BSL in the insulin-glucose group and a mortality reduction that was not apparent at 3 months but became evident at 1 year and was later shown to persist for at least 3 years.

Significance

The DIGAMI-2 study (European Heart Journal. 2005; 26: 650–61) was a multicentre study involving 1253 type 2 diabetics with acute myocardial infarction and randomised patients to three treatment strategies: acute insulin-glucose infusion, then long-term glucose control with insulin, acute insulin-glucose infusion, then maintenance without insulin and a control group without a dictated glucose control regimen that remained institution specific. There was no difference in mortality, non-fatal re-infarction or stroke incidence between the groups. Importantly, however, the HbA1C was not significantly different between groups and there was failure to achieve the tight BSL targets in the long-term insulin group. The question of whether tight glucose control with insulin reduced morbidity and mortality was therefore not adequately answered.

van den Berge G, Wouters P, Weekers F. et al. Intensive insulin therapy in critically ill patients. New England Journal of Medicine. 2001; 345: 1359–67.

Methods

Single-centre, randomised controlled study of 1548 patients in a surgical ICU. Compared intensive insulin therapy for a target BSL of 80–110 mg/dL (4.4–6.1 mmol/L) with conventional insulin (started if BSL >215 mg/dL = 11.9 mmol/L), aiming for a target BSL of 180–200 (10–11.1 mmol/L).

Findings

An absolute reduction in ICU mortality of 3.4% was demonstrated. Reductions in in-hospital mortality, bloodstream infections, acute renal failure requiring renal replacement therapy, blood transfusion rate, incidence of critical-illness polyneuropathy and need for prolonged mechanical ventilation were shown.

Significance

Criticisms of the paper have been many and varied. The baseline mortality of the unit involved in the study has been perceived to be much higher than other such units. It was hypothesised that the benefit could simply have been a reduction in excessive morbidity and mortality associated with overfeeding – a high glucose load was given to their patients in the first 24 hours, including a significant number of patients receiving TPN. Achieving tight BSL targets, without the assistance of dedicated 'BSL nurses' employed by the authors, led to many units that attempted to adopt this strategy finding an unacceptable incidence of hypoglycaemia requiring treatment. The same group went on to perform a single-centre, randomised controlled study in their medical ICU involving 1200 patients projected to require at least 3 days of ICU admission on presentation (van den Berge G, Wilmer A, Hermans G. et al. Intensive insulin therapy in the medical ICU. *New England Journal of Medicine*. 2006; 354: 449–61). Overall, there was no reduction in in-hospital mortality between the two groups, although there was a reduction in morbidity (reduced renal injury, duration of mechanical ventilation, duration of ICU and hospitalisation). Despite the criticisms, the paper sent the ICU community an important message about the potential benefits of achieving improved glucose control.

NICE-SUGAR Study Investigators. Intensive versus conventional glucose control in critically ill patients. *New England Journal of Medicine*. 2009; 360: 1283–97.

Methods

Randomised, unblinded, multicentre study of 6104 patients expected to stay in ICU at least 3 days, stratified according to whether they were surgical or medical ICU admissions. Compared tight (target 81–108 mg/dL = 4.5–6 mmol/L) with conventional blood glucose control (target 144–180 mg/dL = 8–10 mmol/L) for 90 days or until the patient was eating or discharged from the ICU.

Findings

Median treatment duration of approximately 4 days with levels of 115 mg/dL (6.4 mmol) in the tight control group versus 144 mg/dL (8 mmol) in the conventional group. Significant increase in 90-day all-cause mortality seen in the tight glucose control group (27.5% vs 24.9% with a number needed to harm of 38), with increased episodes of severe hypoglycaemia (6.8% vs 0.5%), although a rate lower than in other studies. No difference in hospital or ICU length of stay or duration of mechanical ventilation or renal replacement therapy. Patients received predominantly enteral nutrition with approximately 900 kcal/day in each group only.

Significance

This is the largest study on this topic to date. Criticisms have included the lack of blinding, use of expected length of ICU stay as the entry criteria, underfeeding (in total contrast to the possible overfeeding scenario of the van den Berge papers) and less marked absolute difference in glucose levels between the tight and conventional groups. A convincing scientific rationale for the increased mortality in the tight control group was also missing. After the initial van den Berge paper was published, the authors reported their multivariate regression analysis (*Critical Care Medicine*. 2003; 31: 359–66), which concluded that the lowered glucose level rather than the insulin dose was related to the reduction shown in mortality and other morbidities, with the exception of renal failure, which appeared to be related to the insulin dose. Post-hoc analysis of this kind may help unravel the situation further. A recent systematic review also concluded that there is no evidence to support the use of intensive insulin therapy in general medical–surgical ICU patients (Marik PE, Preiser JC. Towards understanding tight glycemic control in the ICU: a systematic review and meta-analysis. *Chest* 2010; 3: 544–51). Many units are moving away from tight control.

Fluids and electrolytes - Fluid therapy for resuscitation

Finfer S, Bellomo R, Boyce N. et al. A comparison of albumin and saline for fluid resuscitation in the intensive care unit. *New England Journal of Medicine*. 2004; 350: 2247–56.

Methods

Randomised, multicentre, blinded controlled trial involving 6997 mixed ICU patients judged by their clinician to require fluid loads to increase intravascular volume. Patients were resuscitated with 500 mL boluses of either 4% albumin or normal saline. Cardiac surgical, liver transplant and burns patients were excluded.

Findings

There was no difference in 28-day all-cause mortality. No difference was found in incidence of new organ failure, duration of renal replacement therapy, duration of mechanical ventilation, ICU or hospital lengths of stay. Planned subgroup analysis revealed a trend to reduced mortality for albumin in septic shock and an increased mortality in trauma patients, particularly those with traumatic brain injury.

Significance

Previous systematic reviews raised concerns about the safety of colloids in critically ill patients (e.g. Cochrane Database Systematic Review. 2004; 4: CD000567), which this large, well-designed and executed study helped lay to rest. Further studies are still required to establish the precise role of albumin and other colloids. Interestingly, the study also found that the ratio of crystalloid to colloid required to achieve similar therapeutic end-points was only 1:1.4 over the first 4 days of the study. This refuted traditional beliefs that volume ratios of 1:3 are required. The SAFE TBI Study was a post-hoc study that followed up the 460 patients with traumatic brain injuries at 24 months (*New England Journal of Medicine*. 2007; 357: 874–84). It confirmed a significant, increased odds ratio of death in the albumin group. The biologic mechanism remains unclear, although there was a trend to higher intracranial pressures in the albumin group. Another post-hoc study investigated the effect of baseline serum albumin on outcome (SAFE Investigators. *BMJ*. 2006; 333:1044–9). Resuscitation with either fluid produced similar outcomes, irrespective of baseline albumin. Controversy continues as to whether correcting albumin is of any benefit in critically ill patients.

Brunkhorst FM, Engel C, Bloos F, et al. (German Competence Network Sepsis). Intensive insulin therapy and pentastarch resuscitation in severe sepsis. *New England Journal of Medicine*. 2008; 358: 125–39.

Methods

Randomised, multicentre, two-by-two factorial design in 537 patients with severe sepsis who received intensive or conventional insulin therapy and either 10% pentastarch (low-molecular-weight hydroxyethyl starch HES 200/0.5) or modified Ringer's lactate (Sterofundin) for fluid resuscitation.

Findings

The study, known more commonly as the VISEP trial (Efficacy of Volume Substitution and Insulin Therapy in Severe Sepsis), was stopped early due to safety concerns. HES appeared harmful with higher rates of acute renal failure and renal-replacement therapy, and the intensive insulin group (112 mg/dL = 6.2 mmol vs 151 mg/dL = 8.4 mmol) had increased serious adverse events related to hypoglycaemia, although there was no difference in 28-day mortality.

Significance

In Europe, artificial colloids have been more widely used than in other parts of the world, such as Australasia. Starches have long been associated with side effects, such as anaphylactoid reactions, prolonged pruritis, coagulopathy and renal dysfunction. There has been widespread marketing of the low-molecular-weight 6% (grams per 100 mL) HES 130/0.4 as Voluven and Volulyte (Fresenius Kabi). There is a lack of high-quality, adequately powered studies evaluating the safety and efficacy of this product and the VISEP study is a reminder of the potential

of artificial colloids to cause problems. A further shadow has been cast by the revelation of fraudulent research by Joachim Boldt, a leading starch advocate.

Gastroenterology - Feeding

Heyland DK, Dhaliwal R, Drover JW, et al. Canadian Critical Care Clinical Practice Guidelines Committee. Canadian clinical practice guidelines for nutrition support in mechanically ventilated, critically ill patients. Journal of Parenteral and Enteral Nutrition. 2003; 27: 355–73.

Methods

A series of systematic reviews addressing a range of questions related to feeding critically ill patients was performed.

Findings

Recommendations included a preference for enteral nutrition (EN) over parenteral (PN) whenever possible, with the benefit of reduced infectious complications, although no mortality benefit. Early commencement of EN within 24–48 hours using a standard polymeric formula was favoured. Insufficient evidence was found to enable firm conclusions regarding a role for indirect calorimetry, the pH of EN, and the carbohydrate/fat/protein compositions, continuous versus bolus feeding or probiotics. Ongoing clarification remains about the role of PN, including the potential risks of excess lipid delivery causing immune suppression and ARDS. Proponents of TPN still believe past studies involving TPN may be negatively influenced by overfeeding and untreated hyperglycaemia.

Significance

The guidelines are regularly being updated and the key changes from the 2007 and 2009 revisions are available at www.criticalcarenutrition.com. In the head-injured population there was new evidence presented supporting strategies to optimise delivery of nutrients (i.e. starting at a target rate, accepting a higher threshold of gastric residual volumes and small bowel feeding). A feeding protocol incorporating prokinetics at initiation (with metoclopramide being the favoured agent because of safety concerns regarding erythromycin), accepting 250 mL residual volumes and using post-pyloric tubes was generally recommended. Enteral formula with fish oils, borage oils and antioxidants were recommended in ARDS, and glutamine in burns and trauma patients. Supplemental vitamins, trace elements and glutamine are also recommended whenever PN is used.

The European Guidelines are similarly of enormous value (Kreymann KG, Berger MM, Deutz NE, et al. ESPEN Guidelines on enteral nutrition: intensive care. Clinical Nutrition. 2006; 25: 210–23; Singer P, Berger MM, van den Berghe G, et al. ESPEN Guidelines on parenteral nutrition: intensive care. Clinical Nutrition. 2009; 28: 387–400).

Garrel D, Patenaude J, Nedelec B, et al. Decreased mortality and infectious morbidity in adult burn patients given enteral glutamine supplements: a prospective, controlled, randomized clinical trial. Critical Care Medicine. 2003; 31: 2444–9.

Methods

Randomised, double-blind trial in 45 patients with severe burns. Patients received glutamine-enriched EN or an isonitrogenous control mixture until complete wound healing occurred.

Findings

There was a significant reduction in mortality in the glutamine group, as well as a reduction in infectious complications.

Significance

This was the first study, albeit a small one, to show a mortality benefit, as well as a reduction in infection from enteral glutamine formulae. A number of studies have shown a significant mortality benefit and reduced infections from glutamine-enriched PN over standard TPN, although the finding is not universal and the incremental cost is significant.

A range of other additives to EN and PN, as so-called 'immunonutrition', has been investigated. For example, arginine-enriched EN has been found to be ineffective, with at least one study suggesting harm. The optimal role for these agents remains to be established; however, they are being increasingly recommended.

Doig GS, Simpson F, Finfer S, et al. Effect of evidence-based feeding guidelines on mortality of critically ill adults: a cluster randomized controlled trial. JAMA. 2008; 300: 2731–41.

Methods

Cluster randomised trial in 27 community and tertiary hospitals in Australia and New Zealand involving 1118 patients expected to remain in ICU for at least 2 days. They received either a guideline-driven approach facilitated by interventions such as educational outreach visits, or usual practice.

Findings

There was no significant difference in the main outcome measure of hospital discharge mortality. Guideline ICUs fed patients earlier (0.75 vs 1.37 mean days to commencement of EN and 1.04 vs 1.4 mean days until TPN). The mean energy delivered per patient per day and per fed patient per day was not significantly different (1265 vs 1204 kcal/fed patient day). There was no difference in ICU length of stay.

Significance

Patients in both groups were fed early with a similar mean energy delivery. This makes it highly conceivable that the lack of a significant difference between groups led unsurprisingly to a lack of effect on mortality. One interpretation of why this occurred is that despite the massive efforts to encourage guideline compliance this led to little change from the status quo that was already at a reasonable level of practice. Alternatively, centres volunteering for the guideline arm, with all of the associated positive educational support, may have had more baseline problems that they were able to improve and thus line up with other sites. Finally, being in a study alone may have motivated control sites to improve their practices (Hawthorne effect). Feeding is an important therapy and periodic audit to establish compliance with an evidence-based guideline should arguably be part of ensuring quality in any ICU.

Gastroenterology - Gastrointestinal bleeding

Messori A, Trippoli S, Vaiani M, Gorini M, Corrado A. Bleeding and pneumonia in intensive care patients given ranitidine and sucralfate for prevention of stress ulcer: meta-analysis of randomised controlled trials. BMJ. 2000; 321: 1103–6.

Methods

Several meta-analyses were performed evaluating the incidence of bleeding as well as nosocomial pneumonia, which is thought to be a potential adverse effect of gastric acid suppression favouring bacterial overgrowth.

Findings

There was no benefit of ranitidine versus placebo or sucralfate versus placebo, with an increased rate of nosocomial pneumonia with ranitidine compared with sucralfate. All identified studies suffered from small patient numbers.

Significance

Clinically significant stress ulceration has become relatively infrequent with the advent of improved practices of resuscitation and early enteral feeding. It has become clear that mucosal ischaemia is more important than acidity in the pathogenesis of stress ulcers. Despite this reality, the use of proton-pump inhibitors has become more widespread in the critically ill, with data suggesting superiority over H₂ antagonists. Traditional high-risk groups include those patients with a history of peptic ulcer disease, coagulopathy, prolonged shock and those receiving high-dose steroids. Contemporary studies on the efficacy, risks and costs of stress ulcer prophylaxis regimens (including nosocomial pneumonia and cytopenias) are needed. Targeting of therapy to vulnerable groups through evidence-based algorithms may then have substantial cost savings without placing patients at unacceptable risk.

Lau JY, Sung JJ, Lee KK, et al. Effect of intravenous omeprazole on recurrent bleeding after endoscopic treatment of bleeding peptic ulcers. *New England Journal of Medicine*. 2000; 343: 310–16.

Methods

Randomised, double-blind trial of 240 patients with actively bleeding ulcers or ulcers with non-bleeding visible vessels after treatment with epinephrine injections and thermocoagulation received omeprazole (80 mg bolus then 8 mg/hr for 72 hours) or placebo. All patients then received 20 mg oral omeprazole daily for 8 weeks.

Findings

There was a significant reduction in the rate of rebleeding within 30 days (most of which occurred in the first 3 days) in the high-dose omeprazole group. There was no difference in mortality or the number of patients requiring surgery.

Significance

This regimen for high-dose omeprazole has been adopted by many centres in this setting and the results have been replicated more recently by the same group using the S-isomer esomeprazole in a study involving 767 patients (Sung JJ, Barkun A, Kuipers EJ, et al. (Peptic Ulcer Bleed Study Group). Intravenous esomeprazole for prevention of recurrent peptic ulcer bleeding: a randomized trial. *Annals of Internal Medicine*. 2009; 150: 455–64). The same dosing regimen has also been used for IV pantoprazole.

Corley D, Cello J, Adkisson W, Ko W, Kerlikowske K. Octreotide for acute esophageal variceal bleeding: a meta-analysis. *Gastroenterology*. 2001; 120: 946–54.

Methods

Meta-analysis that included results of 13 somewhat heterogeneous studies involving 1077 patients, most of which included less than 100 patients and many of which compared octreotide to another therapy (e.g. terlipressin, vasopressin) rather than placebo. The dosing of octreotide ranged from 50–100 mcg IV bolus, then an infusion of 25–50 mcg/hr for up to 7 days.

Findings

It was concluded that octreotide is superior to other agents and is a safe and effective adjunctive therapy with variceal obliteration techniques.

Significance

Only recently, octreotide was compared to terlipressin in a study involving 324 patients (Abid S, Jafri W, Hamid S, et al. Terlipressin vs. octreotide in bleeding esophageal varices as an adjuvant therapy with endoscopic band ligation: a randomized double-blind placebo-controlled trial. *American Journal of Gastroenterology*. 2009; 104: 617–23). There

was no benefit of one agent over another. A possible role for long-acting octreotide as secondary prevention of variceal bleeding is also being explored.

Hayes PC, Davis JM, Lewis JA, Bouchier IA. Meta-analysis of value of propranolol in prevention of variceal haemorrhage. Lancet. 1990; 336: 153–6.

Methods

Early meta-analysis of controlled trials evaluating beta-adrenoceptor blocking drugs, principally propranolol, in the prevention of primary and secondary variceal bleeding.

Findings

Despite the identification of a need for larger studies, the results indicated the value of propranolol for primary and secondary prevention of variceal bleeding.

Significance

Despite two decades of further investigation, the place of propranolol in prevention of variceal bleeding, particularly in primary prevention remains secure. Combination therapy with nitrates (e.g. ISMN) has not been found beneficial, despite a theoretical synergistic benefit on reducing portal pressure. Endoscopic management does not appear to be superior for primary prevention of bleeding. For acutely bleeding varices, endoscopic band ligation has become conventional management. Sclerotherapy has not proven to be superior or to offer any advantages if used as an adjunct, with an increased incidence of oesophageal strictures. Sclerotherapy remains the most effective therapy for bleeding gastric varices, although the best sclerosant is still the subject of debate. Balloon tamponade (e.g. Sengstaken Blakemore/Minnesota tubes) and transjugular intrahepatic portosystemic shunt (TIPS) remain rescue therapies. The latter has a significant risk of precipitating severe hepatic encephalopathy.

Parsonnet J. Clinician-discoverers – Marshall, Warren and *H. pylori*. New England Journal of Medicine. 2005; 353: 2421–3.

Methods

This brief perspective is about the Western Australian clinicians who won the 2005 Nobel Prize in Physiology or Medicine for their work on *Helicobacter pylori*.

Findings

From seminal observations published in the Lancet in 1983, over 20,000 articles have been indexed in Pubmed.

Significance

Helicobacter pylori is an established cause of chronic superficial gastritis, chronic active gastritis, peptic ulcer disease and gastric adenocarcinoma. The significance of this organism in critically ill patients is under ongoing investigation

Gastroenterology - Pancreatitis

Dellinger EP, Tellado JM, Soto NE, et al. Early antibiotic treatment for severe acute necrotizing pancreatitis: a randomized, double-blind, placebo-controlled study. Annals of Surgery. 2007; 245: 674–83.

Methods

Multicentre, double-blind, placebo-controlled, randomised study in 32 centres in North America and Europe. One

hundred patients with clinically severe, confirmed necrotising pancreatitis received either meropenem (1 g IV every 8 hrs) or placebo.

Findings

The primary end-point was development of pancreatic or peripancreatic infection and no statistically significant difference was identified.

Significance

Despite animal studies suggesting a benefit or prophylactic antibiotics, this study concurs with a similar study (using ciprofloxacin and metronidazole), which also failed to find a benefit (Isenmann R, Runzi M, Kron M, et al. Prophylactic antibiotic treatment in patients with predicted severe acute pancreatitis: a placebo-controlled, double-blind trial. *Gastroenterology*. 2004; 126: 997–1004). Unfortunately, it can be difficult in individual patients to differentiate sepsis from SIRS and withholding antibiotics from a patient with significant pressor requirements and evolving MODS can be enormously challenging. Making decisions based on biochemical markers (e.g. CRP and procalcitonin) is attractive but remains unreliable. This is also an era when there is a lower incidence of infected necrotising pancreatitis than in the past. The situation is complicated by the fact that critically ill patients develop intercurrent infections at other sites (e.g. nosocomial pneumonia) that require antibiotic therapy.

Marik PE, Zaloga GP. Meta-analysis of parenteral nutrition versus enteral nutrition in patients with acute pancreatitis. *BMJ*. 2004; 328: 1407–12.

Methods

Six randomised controlled studies with 263 participants were evaluated.

Findings

Enteral feeding significantly reduced infections, surgical interventions and length of hospital stay, although there was no difference in mortality or non-infectious complications.

Significance

The study helped end decades of concern that enteral feeding exacerbates the disease. Lingering, traditional concerns have prompted studies comparing nasogastric with nasojejunal feeding in severe acute pancreatitis; although to date no large, randomised trials have been completed. Persisting concerns remain, particularly among surgeons, about the risks of reactivation of pancreatitis and the ideal time to initiate feeding. Enteral feeding is increasingly accepted as appropriate and the preferred option for feeding when tolerated. There is no evidence to support the idea that it exacerbates inflammation in the pancreas and it may help maintain gut mucosal function. There are a number of guidelines regarding best practice for pancreatitis (e.g. Isaji S, Kawarada Y, Hirata K, et al. JPN Guidelines for the management of acute pancreatitis: surgical management. *Journal of Hepato-Biliary-Pancreatic Surgery*. 2006; 13: 48–55). The most recent general trends are towards enteral feeding (e.g. Petrov MS, van Santvoort HC, Besselink MG, et al. Enteral nutrition and the risk of mortality and infectious complications in patients with severe acute pancreatitis. *Archives of Surgery*. 2008; 143: 1111–17).

van Santvoort HC, Besselink MG, Bakker OJ, et al. A step-up approach or open necrosectomy for necrotising pancreatitis. *New England Journal of Medicine*. 2010; 362: 1491–502.

Methods

Multicentre, randomised trial involving 88 patients with necrotising pancreatitis who received primary open

necrosectomy or a step-up approach of percutaneous drainage, followed, if needed, by minimally invasive retroperitoneal necrosectomy.

Results

The step-up approach was associated with a reduction in new onset multi-organ failure, reduced incisional hernias and reduced new-onset diabetes without a change in mortality.

Significance

Current trends in pancreatitis management are towards a more conservative, less invasive approach

Haematology/transfusion

Baker R, Coughlin PB, Gallus AS, Harper PL, Salem HH, Wood EM. Warfarin reversal: consensus guidelines, on behalf of the Australasian Society of Thrombosis and Haemostasis. Medical Journal of Australia. 2004; 181: 492–7.

Methods

Evidence-based recommendations regarding rationalisation for various approaches linked to risk of bleeding.

Findings

Prothrombin complex concentrate (PCC) and fresh frozen plasma (FFP) are indicated for immediate reversal. Oral vitamin K for slower reversal or to sustain reversal once achieved, but not in supratherapeutic doses that cause warfarin resistance when it is re-instated.

Significance

PCCs have become the mainstay of immediate warfarin reversal. It is more effective than with FFP alone and the volumes required are significantly lower. The necessity for adjunctive FFP is being questioned. A number of products are available internationally.

Corwin HL, Gettinger A, Pearl RG, et al. Efficacy of recombinant human erythropoietin in critically ill patients: a randomized controlled trial (EPO Critical care Trials). JAMA 2002; 288: 2827–35.

Methods

Multicentre, randomised, double-blind trial, recruiting 1302 patients, of weekly subcutaneous recombinant human erythropoietin (40,000 units) vs placebo in ICU patients staying beyond 2 days, for up to 3 doses.

Findings

Approximately 20% reduction in red blood cell (RBC) transfusion in the EPO group.

Significance

This study stimulated the investigators to perform a further study involving 1460 patients to look for other clinically relevant outcomes. It did not show a reduction in RBC transfusion, but suggested a reduction in mortality in trauma patients and an overall increase in thrombotic events (Corwin HL, Gettinger A, Fabian TC, et al. Efficacy and safety of epoetin alfa in critically ill patients. New England Journal of Medicine. 2007; 357: 965–76).

There is a risk of life-threatening red cell aplasia with some EPO preparations. The newer agent, darbopoietin, has a reduced risk of this complication, with a longer duration of action, but has not been evaluated in this context. It has

become the drug of choice for chronic renal failure patients. These are expensive agents and concerns also exist regarding a range of complications, including thromboembolism and in cancer patients, accelerated tumour growth (there have been FDA warnings regarding EPO use in patients receiving chemotherapy for cancer). Reducing exposure to blood products is attractive and this strategy may be significantly underutilised. Interestingly, EPO continues to be explored as a promising neuroprotective and neuroregenerative agent potentially via antiapoptotic effects. In the future it may have a role in populations commonly managed in ICU, such as patients with traumatic brain injury, as the most recent Corwin Paper has stimulated renewed interest in this area.

Hebert PC, Wells G, Blajchman MA, et al. A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. Transfusion Requirements in Critical Care (TRICC) Investigators, Canadian Critical Care Trials Group. New England Journal of Medicine. 1999; 340: 409–17.

Methods

Involved 838 normovolaemic critically ill patients randomised to a transfusion threshold of 7 versus 10 g/dL.

Findings

There was no difference in 30-day mortality, but a significant reduction in blood product exposure with the more restrictive group.

Significance

This is a seminal paper that questioned the liberal approach to transfusion in existence at the time. The study does not pertain to hypovolaemic or bleeding patients and was not powered to look at patients with cardiovascular disease (e.g. ischaemic heart disease or heart failure), severe sepsis or acute cerebrovascular disease. A prospective observational study of patients with acute myocardial infarction found that although both anaemia and transfusion of RBC are associated with worse outcomes, there appears to be the most potential for harm if transfusion is given to patients with a Hb >8 g/dL (Aronson D, Dann EJ, Bonstein L, et al. Impact of red blood cell transfusion on clinical outcomes in patients with acute myocardial infarction. American Journal of Cardiology. 2008; 102: 115–19).

Corwin HL, Gettinger A, Pearl RG, et al. The CRIT Study: Anemia and blood transfusion in the critically ill – current practice in the United States. Critical Care Medicine. 2004; 32: 39–52.

Methods

Prospective, multicentre, observational cohort study of 4892 ICU patients in the US with 30-day follow-up, during which haemoglobin and transfusions were monitored.

Findings

The mean pretransfusion threshold was 8.6 g/dL. The number of units transfused was an independent predictor of worse outcome.

Significance

This study suggested that there has been little change in transfusion practices in the post-TRICC era. The European ABC similarly showed that transfusion was positively associated with increased mortality (Vincent JL, Baron JF, Reinhart K, et al. Anemia and blood transfusion in critically ill patients. JAMA. 2002; 288: 1499–1507), although others suggest the opposite. It remains unclear if transfusion is merely a marker of illness severity. Blood storage 'lesion' with haemolysis and endothelial dysfunction and the effects of transfused leucocytes are possible mechanisms of injury. Non-leucodepleted blood has been associated with febrile non-haemolytic transfusion reactions, platelet allo-immunisation, cell-associated infectious agent transmission (e.g. prions, CMV), graft vs host

disease (GVHD), transfusion-related acute lung injury (TRALI), transplant rejection (e.g. renal grafts) and possibly post-surgical wound infection and cancer recurrence. Studies are needed to define the risks of transfusion in the current age of prestorage universal leucodepletion of blood supplies.

Mayer SA, Brun NC, Begtrup K, et al. Recombinant Activated Factor VII Intracerebral Hemorrhage Trial Investigators. Recombinant activated factor VII for acute intracerebral hemorrhage. New England Journal of Medicine. 2005; 352: 777–85.

Methods

Multicentre, randomised, double-blind trial of 399 patients with an acute intracerebral haemorrhage. This was a phase II study in which participants received a single intravenous injection of recombinant factor VIIa – 40 mcg, 80 mcg or 160 mcg/kg, or placebo within 1 hour of their baseline CT scan.

Findings

There was a significant reduction in the volume of the haematoma on CT scan at 24 hours. There was a significant reduction in 90-day mortality without an apparent increase in the number of severely disabled patients. There was no statistically significant increase in serious thromboembolic events.

Significance

This agent had the possibility of making a significant difference to the prognosis of acute intracerebral haemorrhage, but was not powered for outcome. Unfortunately, the definitive study that followed it did not show the anticipated improvement in functional outcome (Mayer S, Brun N, Begtrup K, et al. Efficacy and safety of recombinant activated factor VII for acute intracerebral haemorrhage. New England Journal of Medicine. 2008; 358: 2127–37).

There has been much enthusiasm for factor VIIa, which has stemmed from its efficacy in the management of haemophilias. Large numbers of case series (including registry data) and review articles have been published that explore the off-label role of this expensive agent in a number of settings where severe bleeding is encountered. These include trauma, obstetric haemorrhage and major surgery, especially cardiac, but without robust evidence from studies such as those performed in intracranial haemorrhage. The most appropriate dose also remains unclear.

Depuydt PO, Benoit DD, Vandeoude KH, et al. Outcome in noninvasively and invasively ventilated hematologic patients with acute respiratory failure. Chest. 2004; 126: 1299–306.

Methods

Retrospective study of 166 consecutive patients with haematological malignancies and acute respiratory failure requiring mechanical ventilation. The study aimed to determine the effect of non-invasive ventilation versus intubation and ventilation.

Findings

They found a high overall in-hospital mortality of 71%. Only 27 patients received non-invasive ventilation and 102 were intubated. The non-invasive group were matched with 52 patients with similar illness severity (SAPS II scores) and no difference in mortality was found. A subset of 55 patients requiring renal replacement therapy had a 92% in-hospital mortality. Female sex, a recent positive blood culture and early intubation (within 24 hours) were identified as being associated with better outcomes.

Significance

Despite the limitations of the study, which was retrospective, non-randomised and in a single centre, it provides an

insight into the range of predictive factors associated with outcome in patients with haematological malignancies. It is in contrast to some previous studies that associated mechanical ventilation with very bleak outcomes. The management of critically ill cancer patients is an area of increasing focus, as many conditions are associated with more encouraging results than in the past.

Brunskill SJ, Tusold A, Benjamin S et al. A systematic review of randomized controlled trials for plasma exchange in the treatment of thrombotic thrombocytopenic purpura. Transfusion Medicine. 2007; 17: 17–35.

Methods

Systematic review of seven randomised controlled trials comparing plasma exchange with plasma infusion for patients with thrombotic thrombocytopenic purpura.

Findings

Plasma exchange had a mortality benefit.

Significance

This is a rare, life-threatening condition and further studies are needed to identify the best protocol for this therapy, including the role of other therapies such as haemofiltration. The role of plasma exchange in critically ill patients requires further analysis of cohorts with studies such as this and that used in Guillain-Barré syndrome, where immunoglobulin therapy was found to be superior. Other conditions needing further evaluation include: myasthenia gravis, Goodpasture's syndrome, Wegener's granulomatosis, antiphospholipid syndrome, hyperviscosity syndromes, sickle cell crises, HELLP syndrome, demyelinating disorders, transplant rejection, hypercholesterolaemia and pancreatitis.

Monitoring devices

Connors AF Jr, Speroff T, Dawson NV, et al. The effectiveness of right heart catheterization in the initial care of critically ill patients. SUPPORT Investigators. JAMA 1996; 276: 889–97.

Methods

Prospective, multicentre cohort study of 5735 critically ill patients. Case-matching and multivariable regression modelling techniques were used to estimate the association of pulmonary artery (PA) catheters with specific outcomes.

Findings

An increase in mortality and resource utilisation was found in the catheter group.

Significance

A moratorium on PA catheter usage was subsequently called for, pending results of randomised trials. This was met by the New Horizons symposium, a consensus conference dominated by expert opinion and, although trials were called for, PA catheter usage continued.

Harvey S, Harrison DA, Singer M, et al. Assessment of the clinical effectiveness of pulmonary artery catheters in management of patients in intensive care (PAC-Man): a randomised controlled trial. Lancet 2005; 366: 472–7.

Methods

Multicentre, randomised controlled trial of 1041 ICU patients, where the treating clinician deemed it beneficial to insert a PA catheter. Patients who had a catheter already inserted on arrival (e.g. from an operating theatre), or who were being electively admitted for preoperative optimisation were excluded. The catheter remained in situ for as long as was felt clinically necessary.

Findings

There was no difference in hospital mortality between patients with or without the device. Complications noted were predominantly associated with central venous cannulation, none of which was fatal.

Significance

The Fluids and Catheters Treatment Trial (FACTT) (Pulmonary artery versus central venous catheter to guide treatment of acute lung injury. *New England Journal of Medicine*. 2006; 354: 2213–24) evaluated the relationship of benefits and risks in 1000 patients with acute lung injury for guidance of conservative versus liberal fluid strategies (see later ARDS section for more details). There was no improvement in survival or organ function and an increase in catheter-related complications in the PA catheter group. The study was reassuring, in that PA catheters were not shown to be associated with an independent mortality.

There was also no benefit found when PACs were used in high-risk surgical patients. In a randomised trial involving 1994 elderly patients, individuals received either a PA catheter and goal-directed therapy (interventions including fluids, packed cells and vasoactive drugs, to achieve an oxygen delivery of 550–600 mL/min/m² body area, CI 3.5–4.5 L/min/m² body area, PCWP 18 mmHg, MAP 70 mmHg, HR < 120/min, haematocrit >27%) or standard therapy (central venous pressures permitted but no strict haemodynamic goals) (Sandham JD, Hull RD, Brant RF, et al. A randomized, controlled trial of the use of pulmonary-artery catheters in high-risk surgical patients. *New England Journal of Medicine*. 2003; 348: 5–14). Despite these negative studies, PACs remain in the armamentarium of tools to facilitate haemodynamic assessment and management. However, they are under challenge from less invasive techniques, including pulse contour analysis devices, oesophageal Doppler and echocardiography, although none has been as extensively studied.

Shoemaker WC, Appel PL, Kram HB, et al. Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients. *Chest* 1988; 94: 1176–86.

Methods

The study involved small numbers of high-risk surgical patients. Right heart catheters and interventions (fluids and vasoactive drugs) were employed to achieve targets (CI of 4.5, oxygen delivery of 600 mL/min/m² and oxygen consumption >170 mL/min/m²) in the treatment group. There were two other standard groups utilising a right heart catheter with lesser targets, and a group using CVP-driven therapy alone.

Findings

A reduction in mortality was reported for patients receiving supranormal oxygenation.

Significance

This was the first study that attempted to find a benefit for 'supranormal oxygen delivery'. This approach is based on the work of a group of investigators who demonstrated that in some critically ill patients there is co-variation in oxygen supply and demand, which implies that some individuals may have an unmet metabolic demand despite normal ranges of measured oxygen delivery (Danek S, Lynch JP, Weg JG, Dantzker DR. The dependence of oxygen uptake on oxygen delivery in the adult respiratory distress syndrome. *American Review of Respiratory Disease*. 1980; 122:

387–95). Shoemaker et al. hypothesised that increasing tissue supply may improve tissue function and reduce morbidity and mortality. This paper has been extensively criticised for reasons, such as a lack of randomisation with a lack of similarity between treatment groups. Several other studies subsequently attempted to evaluate supranormal oxygenation, showing either no benefit (Gattinoni L, Brazzi L, Pelosi P. et al. A trial of goal-oriented haemodynamic therapy in critically ill patients. *SvO₂ Collaborative Group*. 1995; 333: 1025–32) or an increase in morbidity and mortality (Hayes MA, Timmins Ac, Yau EH, et al. Elevation of systemic oxygen delivery in the treatment of critically ill patients. *New England Journal of Medicine*. 1994; 330: 1717–22). Some argue that the initial premise was incorrect and the oxygen delivery and consumption co-dependency was a spurious result of mathematical coupling systematically introduced by using cardiac output measurements from PA catheter measurements in calculating both numbers. No such relationship is found when oxygen consumption is measured with indirect calorimetry (Hanique G, Dugernier T, Laterre PF, et al. Significance of pathologic oxygen supply dependency in critically ill patients: comparison between measured and calculated methods. *Intensive Care Medicine*. 1994; 20: 12–18).

Hind D, Calvert N, McWilliams R, et al. Ultrasonic locating devices for central venous cannulation: meta-analysis. *BMJ*. 2003; 327: 361–7.

Methods

These authors analysed 18 trials involving 1646 patients undergoing cannulation of their central veins. Success and complications were compared in identified studies that randomised subjects to either the landmark method or real-time two-dimensional ultrasound guidance.

Findings

In adults, the Doppler method was found to be more successful overall and on the first attempt for the internal jugular vein with fewer complications.

Significance

It is becoming indefensible to obtain central venous access without ultrasonic guidance, as recommendations for best practice strenuously advocate this technique. The evidence is also mounting to support a shorter learning curve for the technique. There are logical benefits of using ultrasound to assist insertion of invasive lines at other anatomic locations. Aberrant anatomy is more common than is generally appreciated. Concerns exist regarding the de-skilling of operators such that they will be unable to perform central venous cannulation in emergencies without ultrasound.

Cheatham M, Safcsak K. Is the evolving management of intra-abdominal hypertension and abdominal compartment syndrome improving survival? *Critical Care Medicine*. 2010; 38: 692–3.

Methods

Prospective, observational, single-centre study enrolling 478 consecutive patients in ICU into a pathway for diagnosis and management of abdominal compartment syndrome using serial intraabdominal pressure readings. Uni- and multivariate regression analysis were used to identify factors associated with improved survival.

Findings

There was a statistically significant hospital mortality benefit and increased rate of primary fascial closure in patients with more aggressive intervention without an increase in resource utilisation.

Significance

The approach recommended early opening of the abdomen, including prophylactic opening in high-risk patients. This is an area of ongoing interest and the World Society of the Abdominal Compartment Syndrome continue to produce

recommendations for monitoring, medical and surgical treatments to reduce intra-abdominal hypertension and thresholds for interventions. Go to www.wsacs.org.

Neurology - Guillain-Barre Syndrome

Plasma Exchange/Sandoglobulin Guillain-Barré Syndrome Trial Group. Randomised trial of plasma exchange, intravenous immunoglobulin, and combined treatments in Guillain-Barré syndrome. Lancet. 1997; 349: 225–30.

Methods

Multicentre, randomised trial of 383 patients with Guillain-Barré syndrome who received either plasma exchange (five 50 mL/kg exchanges over 8–13 days) or intravenous immunoglobulin (0.4 g/kg daily for 5 days) or the plasma exchange followed by the immunoglobulin regimens. Treatment was instituted during the first 2 weeks after the onset of symptoms.

Findings

There was no difference in disability scores, time to recovery of independent mobility or duration of mechanical ventilation between the treatment groups.

Significance

The paper provides efficacy data for immunoglobulin, which is a simpler, less labour-intensive method of treatment compared to plasma exchange.

Neurology - Hypoxic-ischaemic brain injury

Zandbergen EG, de Haan RJ, Stoutenbeek CP, et al. Systematic review of early prediction of poor outcome in anoxic-ischaemic coma. Lancet 1998; 352: 1808–12.

Methods

Systematic review, which included 33 studies evaluating 14 prognostic variables.

Findings

Three variables with a specificity of 100% were: absence of pupillary light reflexes at day 3, absent motor response to pain (worse than withdrawal) on day 3 and bilateral absence of early cortical SSEP (somato-sensory evoked potentials) within the first week. Most studies also found that an isoelectric EEG, or one with burst suppression, also had a very high specificity for poor outcomes.

Significance

These have been the traditional prognostic factors used by intensivists to guide cessation of active therapy. In the era of therapeutic hypothermia after cardiac arrest the rules are changing. It is recognised that a further period of observation is required to make a meaningful assessment due to the unpredictable effects of hypothermia on cerebral function and to enable elimination of sedative and paralytic agents frequently administered to patients so they tolerate cooling. Liver and renal dysfunctions are other confounding factors as they delay drug disposition. The best combination of clinical testing and objective assessment (e.g. EEG, SSEP and imaging) indicated for these patients remains unclear. It is likely that acute post-anoxic generalised myoclonus remains a very poor prognostic marker (Thomke F, Marx JJ, Sauer O, et al. Observations on comatose survivors of cardiopulmonary resuscitation with

generalized myoclonus. BMC Neurology. 2005; 5: 14). It is classically transient, exacerbated by stimulation and poorly responsive to anticonvulsants, although sodium valproate, levatiracetam and propofol may be useful

Neurology - Stroke

Hart RG, Benavente O, McBride R, Pearce LA. Antithrombotic therapy to prevent stroke in patients with atrial fibrillation: a meta-analysis. Annals of Internal Medicine. 1999; 131: 492–501.

Methods

The paper included 16 trials with a total of 9874 patients.

Findings

Warfarin and aspirin both reduce stroke in patients with atrial fibrillation (AF), with warfarin being significantly better than aspirin. Benefits were not offset by the incidence of major bleeding: absolute risk with warfarin of 0.3% per year for major extracranial haemorrhages.

Significance

Antithrombotic therapy should be offered to all patients with chronic AF. The choice between aspirin and warfarin should be based upon the perceived risk of bleeding for an individual patient.

CAPRIE Steering Committee. A randomised, blinded, trial of clopidogrel versus aspirin in patients at risk of ischaemic events (CAPRIE). 1996; 348: 1329–39.

Methods

Randomised, blinded, multicentre international study recruiting 19,185 patients, comparing clopidogrel (75 mg daily) with aspirin (325 mg daily) for prevention of the combined outcome of 'vascular death, nonfatal stroke or nonfatal myocardial infarction'.

Findings

Clopidogrel was associated with a relative risk reduction of 8.7% (absolute reductions of 5.32% vs 5.83%) on the annual risks of a vascular event. There was more rash and diarrhoea with clopidogrel, but more upper gastrointestinal symptoms and haemorrhages with aspirin.

Significance

This study helped answer the question of whether clopidogrel offered equivalent or superior benefits in terms of vascular end-points. Although it did not look at stroke prevention alone, it studied meaningful end-points that are important from a patient perspective. A Cochrane review, evaluating the relative value of aspirin and ADP antagonists (ticlopidine and clopidogrel), demonstrated a small but significant superiority in high-risk patients. Ticlopidine had a greater incidence of neutropaenia and thrombotic thrombocytopenic purpura that has led to favouring of clopidogrel (Hankey GJ, Sudlow CL, Dunbabin DW. Thienopyridine derivatives (ticlopidine, clopidogrel) versus aspirin for preventing stroke and other serious vascular events in high vascular risk patients. Cochrane Database Systematic Reviews. 2009; 4: CD001246).

Chen ZM, Sandercock P, Pan HC, et al. Indications for early aspirin use in acute ischemic stroke: A combined analysis of 40000 randomized patients from the Chinese acute stroke trial and the international stroke trial. On behalf of the CAST and IST collaborative group. Stroke. 2000; 31: 1240–9.

Methods

This paper presents the combined results of two large, randomised trials, each involving approximately 20,000 patients.

Findings

Daily aspirin, started promptly in patients with suspected acute ischaemic stroke, reduces the immediate risk of further stroke and in-hospital death. There was no significant increase in the risk of haemorrhagic stroke in patients given aspirin prior to CT scanning. There was also no increase in mortality or further strokes in those who were given aspirin inadvertently after a haemorrhagic stroke.

Significance

The evidence favouring a benefit of aspirin after ischaemic stroke is very robust. Conversely, there is no benefit of intravenous unfractionated or low-molecular weight heparin, with an increased risk of haemorrhagic stroke transformation.

Diener HC, Bogousslavsky J, Brass LM, et al. (MATCH investigators). Aspirin and clopidogrel compared with clopidogrel alone after recent ischaemic stroke or transient ischaemic attack in high-risk patients (MATCH): randomised, double-blind, placebo-controlled trial. Lancet. 2004; 364: 331–7.

Methods

Randomised, double-blind, placebo-controlled trial involving 7599 high-risk patients (recent ischaemic stroke or transient ischaemic attack) who received aspirin (75 mg daily) or placebo in addition to clopidogrel (75 mg daily).

Findings

No significant benefit found by adding aspirin to clopidogrel.

Significance

This was the first of several large, randomised trials comparing various antiplatelet combinations for secondary stroke prevention. It was followed by CHARISMA, which found no benefit of adding clopidogrel to aspirin (Bhatt DL, Fox KAA, Hacke W, et al. (CHARISMA Investigators). Clopidogrel and aspirin versus aspirin alone for the prevention of atherothrombotic events. New England Journal of Medicine. 2006; 354: 1706–17). ESPRIT found superiority of an aspirin–dipyridamole combination over aspirin alone (Halkes PH, van Gijn J, Kappelle LJ, et al. (ESPRIT Study Group). Aspirin plus dipyridamole versus aspirin alone after cerebral ischaemia of arterial origin (ESPRIT): randomised controlled trial. Lancet. 2006; 367:1665–73). The PROFESS study was the largest study and compared two antiplatelet approaches, as well as telmisartan with placebo. It found similar efficacy of aspirin–dipyridamole and clopidogrel, with less haemorrhagic events with clopidogrel and no benefit of telmisartan (Sacco RL, Diener HC, Yusuf S, et al. (PROFESS Study Group). Aspirin and extended-release dipyridamole versus clopidogrel for recurrent stroke. New England Journal of Medicine. 2008; 359: 1238–51). Debate continues regarding the studies and their limitations, and the best agent(s) and dosing regimens.

Mendelow AD, Gregson BA, Fernandes HM, et al. STICH Investigators. Early surgery versus initial conservative treatment in patients with spontaneous supratentorial intracerebral haematomas in the International Surgical Trial in Intracerebral haemorrhage (STICH): a randomised trial. Lancet. 2005; 365: 387–97.

Methods

Multicentre, randomised parallel-group controlled trial with 1033 patients with acute supratentorial intracerebral

haemorrhage. Participants either received early surgery and haematoma evacuation (within 24 hours of randomisation) with medical treatment or initial conservative treatment, with delayed surgery if needed.

Findings

There was no significant difference in the number of patients with favourable neurologic outcomes at 6 months as assessed by the Extended Glasgow Outcome Scale. The study importantly excluded patients with suspected aneurysms or arteriovenous malformations and haemorrhages extending into the brainstem or in the cerebellum.

Significance

The delay to surgery in the 'early' group, where less than 20% of subjects were operated on within 12 hours, has been a major criticism. The surgical method employed was at the discretion of the treating neurosurgeon, with the majority of patients receiving a craniotomy. Some neurosurgeons, favouring minimally invasive surgery, argue that this may have been a major factor contributing to the studies lack of efficacy. There are a number of options for managing supratentorial haemorrhages: conservative therapy, simple aspiration, and craniotomy with open evacuation, endoscopic or stereotactic evacuation. Application of the various options remains highly variable with large regional differences. More high-quality randomised studies are needed.

In contrast, cerebellar haematomas are generally managed with suboccipital craniotomy and evacuation when there are features of brainstem compression as observational studies have shown this to be favourable with good neurologic outcomes (Hankey GJ. Evacuation of intracerebral hematoma is likely to be beneficial – against. American Heart Association. 2003; 34: 1568).

Tissue plasminogen activator for acute ischemic stroke. The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. New England Journal of Medicine. 1995; 333: 1581–7.

Methods

Randomised, double-blind trial of intravenous recombinant tissue plasminogen activator (rt-PA – 0.9 mg/kg with 10% of the dose over 1–2 minutes and the rest over 2 hours with a maximal dose of 90 mg) for ischaemic stroke, delivered within 3 hours of the onset of neurological signs. There were two parts to the study, involving a total of 624 patients, each evaluating different measures of efficacy.

Findings

Both parts confirmed a lack of early benefit, but a significant improvement in functional status at 3 months. There was a significant increase in intracranial haemorrhage in the rt-PA group (6.4% vs 0.6%).

Significance

A number of studies of this kind were performed in the mid-1990s. A meta-analysis combined the results of six randomised controlled trials involving 2775 patients treated within 360 minutes of stroke onset with rt-PA or placebo. A favourable neurological outcome at 3 months was associated with lysis, which increased as time to receipt of thrombolysis decreased. The risk of intracranial haemorrhage was 5.9% (lysis group) versus 1.1% (control group) and unrelated to the time to treatment (Hacke W, Donnan G, Fieschi C, et al. Association of outcome with early stroke treatment: pooled analysis of ATLANTIS, ECASS, and NINDS rt-PA stroke trials. Lancet 2004; 363: 768–74).

del Zoppo GJ, Higashida RT, Furlan AJ, et al. PROACT: A phase II randomized trial of recombinant pro-urokinase by direct arterial delivery in acute middle cerebral artery stroke. Stroke. 1998; 29: 4–11.

Methods

Randomised study of 46 patients with abrupt onset ischaemic symptoms, with haemorrhage excluded with CT and an occlusion of the M1 or M2 middle cerebral artery on carotid angiography. They received recombinant pro-urokinase or placebo within 6 hours of symptom onset.

Findings

Significantly more patients in the pro-urokinase group recannalised but also experienced haemorrhagic transformation.

Significance

This was followed by the PROACT II study, a larger multicentre study that compared intra-arterial pro-urokinase and heparin with heparin alone for patients meeting similar criteria. It again found that pro-urokinase increased recannalisation, with an increase in intracranial haemorrhage, but also a significant improvement in 90-day clinical outcomes (Furlan A, Higashida R, Wechsler L, et al. Intra-arterial pro-urokinase for acute ischemic stroke. The PROACT II study: a randomized controlled trial. *Prolyse in Acute Cerebral Thromboembolism*. JAMA. 1999; 282: 2003–11). Studies are ongoing to compare the relative safety and efficacy of intra-arterial versus intravenous thrombolysis (e.g. SYNTHESIS trial). Controversy also continues regarding the optimal imaging investigation to rapidly detect suitable patients, as well as clarification of patient factors associated with the least bleeding risk. Thrombolysis for ischaemic stroke remains an option for a select minority of patients who present very early (within 3 and possibly up to 6 hours).

Smith WS, Sung G, Starkman, et al. Safety and efficacy of mechanical embolectomy in acute ischemic stroke. Results of the MERCI Trial. Stroke. 2005; 36: 1432–8.

Methods

Prospective, non-randomised, multicentre trial of patients ineligible for intravenous thrombolysis using an embolectomy device (Merci Retriever) to open occluded intracranial large vessels within 8 hours of symptom onset.

Findings

Recannalisation was achieved in approximately half of all patients, more than half the success rate than in historical controls. Mortality was significantly reduced and neurologic outcomes improved at 90 days in those who recannalised compared to those who did not.

Significance

Embolectomy is another new therapy undergoing investigation and others have followed this study. Multi MERCI examined the performance of a second generation device in the same setting, demonstrating non-statistically significant improvement in recannalisation rates (Smith WS, Sung G, Budzik R, et al. Mechanical thrombectomy for acute ischemic stroke: final results of the Multi MERCI trial. *Stroke*. 2008; 39: 1205–12). The Penumbra device is an alternate retrieval system similarly investigated and has performed well in early studies (Penumbra Pivotal Stroke Trial Investigators. The Penumbra Pivotal Stroke Trial. *Stroke*. 2009; 40: 2761–8).

Levy EI, Siddiqui AH, Crumlish A, et al. First Food and Drug Administration-approved prospective trial of primary intracranial stenting for acute stroke: SARIS (stent-assisted recannalization in acute ischemic stroke). Stroke. 2009; 40: 3553–6.

Methods

Prospective pilot trial of 20 patients who received intracranial stenting for acute ischaemic strokes presenting less

than 8 hours from symptom onset with a favourable focal arterial occlusion with a contraindication to thrombolysis or within 1 hour of failed lysis.

Findings

Recanalisation was improved, with a trend of improved neurologic outcomes at 1 month.

Significance

Stenting is another growing area of investigation. Studies such as SARIS will no doubt flourish. Interventional radiology is exploding in terms of the options for treating a range of intracranial catastrophes, as well as offering definitive management for high-risk asymptomatic lesions

Neurology - Subarachnoid haemorrhage

Molyneux AJ, Kerr RS, Yu, et al. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. Lancet 2005; 366: 809–17.

Methods

Multicentre study comparing craniotomy and clipping with endovascular detachable-coil treatment in patients where both treatments are appropriate (i.e. >90% of aneurysms were small (<10 mm) and involved the anterior circulation).

Findings

The study showed that coiling resulted in more independent survivors at 1 year, which continues for at least 7 years. There was a low risk of re-bleeding, but this was more common after coiling.

Significance

This study drove enthusiasm for coiling, although it is not available in all neurosurgical centres. It should not be forgotten that coiling may be superior in high-risk surgical candidates with co-morbid chronic medical disorders and posterior circulation lesions, especially where the aneurysm has a narrow neck. Technological developments enabling endovascular therapies are continuing to expand the scope of aneurysms that may be coiled.

Pickard JD, Murray GD, Illingworth R, et al. Effect of oral nimodipine on cerebral infarction and outcome after subarachnoid haemorrhage: British aneurysm nimodipine trial. BMJ 1989; 298: 636–42.

Methods

Randomised, controlled multicentre trial involving 554 patients with subarachnoid haemorrhage comparing oral nimodipine (60 mg every 4 hours for 21 days, started within 96 hours of the haemorrhage) with placebo.

Findings

Nimodipine was shown to reduce the incidence of cerebral infarction and poor neurological outcomes at 3 months.

Significance

Nimodipine was evaluated as prophylaxis for arterial vasospasm in this study. Other investigators have not replicated the results. There is also no robust evidence supporting the practice of intravenous nimodipine infusions. Angiographically directed vasodilators (e.g. verapamil) may provide short-term reversal of established vasospasm, although a sustained effect or outcome benefit has not been confirmed and there are risks associated with this

invasive procedure. Some centres use percutaneous balloon angioplasty for proximal vasospasm and dilator agents for distal lesions. Intra-arterial directed papaverine has been associated with only transient effects and a steal effect by preferentially dilating unaffected vessels.

Treggiari MM, Walder B, Suter PM, Romand A. Systematic review of the prevention of delayed ischemic neurological deficits with hypertension, hypervolemia, and hemodilution therapy following subarachnoid hemorrhage. Journal of Neurosurgery. 2003; 98: 978–84.

Methods

Studies between 1966 and 2001 were sought.

Findings

Only four prospective, comparative studies were identified, involving a total of 488 patients with subarachnoid haemorrhage. Compared with no treatment, 'triple H' therapy was associated with a reduced risk of symptomatic vasospasm but an increased risk of death. The study quality was generally poor.

Significance

There is poor evidence supporting this therapeutic combination and further studies are warranted. There are risks associated with this therapy (e.g. fluid and electrolyte derangements and vasoactive drug-related complications) and it should only be performed as part of a monitored strategy, individualised to the patient's physiology. Maintaining normovolaemia and avoiding hypotension appear to be rational low-risk strategies.

Wong GK, Chan MT, Boet R et al. Intravenous magnesium sulfate after aneurysmal subarachnoid hemorrhage: a prospective randomized pilot study. Journal of Neurosurgery and Anesthesiology. 2006; 18:142–8.

Methods

Randomised, double-blind, pilot study of 60 patients with subarachnoid haemorrhage. They received either MgSO₄ (80 mmol/day) or saline via an infusion for 14 days in addition to nimodipine.

Findings

There was a non-statistically significant reduction in the incidence of symptomatic vasospasm decreased from 43% (saline group) to 23%. There was no difference in terms of functional recovery or Glasgow Outcome Scale.

Significance

This study was based on animal models demonstrating a positive effect of magnesium in experimental models of vasospasm. It was followed by other larger studies that have had mixed findings and some of these are ongoing.

A range of drug therapies have been investigated and continue to be evaluated for prevention of vasospasm. Nitric oxide donors, endothelin-1 antagonists, dapsone and statins are other promising agents. Interventions that aid clearance of blood from the CSF (e.g. intra-cisternal irrigation with thrombolysis and lumbar CSF drainage) have also been explored. Evidence to support these therapies awaits future trials.

Obstetrics and Gynaecology

Altman D, Carroli G, Duley L, et al. Do women with pre-eclampsia, and their babies, benefit from magnesium sulphate? The Magpie Trial: a randomised placebo-controlled trial. Lancet 2002; 359: 1877–90.

Methods

International, multicentre, randomised, controlled trial of magnesium sulfate (e.g. 4 g loading dose then 1 g/hr intravenously) versus placebo. Involved 10,141 women with pre-eclampsia.

Findings

A significant reduction in eclampsia and maternal mortality, but no difference in the risk of the baby dying. Magnesium was also well tolerated with few side effects, the most common being maternal flushing.

Significance

Magnesium sulfate is a first line treatment for pre-eclampsia. This was one of the largest studies performed in obstetric patients.

This is only part of an overall management algorithm for treating hypertension in pregnancy. Recent guidelines provide an update of various aspects of care and define the ongoing challenges (Lowe SA, Brown MA, Dekker GA, et al. (Society of Obstetric Medicine of Australia and New Zealand). Guidelines for the management of hypertensive disorders of pregnancy. Australian and New Zealand Journal of Obstetrics and Gynaecology, 2008. 2009; 49: 242–6).

Brown BJ, Heaston DK, Poulson AM, et al. Uncontrollable postpartum bleeding: a new approach to hemostasis through angiographic arterial embolization. Obstetrics and Gynecology. 1979; 54: 361–5.

Methods

Case report.

Findings

A patient with severe primary postpartum haemorrhage who was bleeding, despite three separate surgical procedures including bilateral ligation of the hypogastric arteries, underwent angiography. A specific bleeding vessel was managed with transcatheter embolisation with gelfoam fragments.

Significance

This was the first report of a new therapy that has become routine practice for refractory bleeding. Uterine artery embolisation is a fertility-preserving rescue option and can also be used pre-emptively in women at high risk of torrential bleeding (e.g. placenta increta). The subsequent evidence remains largely in the realm of case series. Recombinant factor VIIa may offer an adjunctive benefit for management of refractory postpartum bleeding. There is generally an absence of randomised trials to support therapies for obstetric emergencies

Pain medicine

Acute Pain Management: Scientific Evidence Australian and New Zealand College of Anaesthetists and Faculty of Pain Medicine 2005.

Methods

This purpose of this document is to provide evidence-based management of acute pain. The levels of evidence provided are based according to the NHMRC designation defined in 1999. The guidelines are divided into 10 groups, including the physiology and psychology of acute pain, assessment, systemically administered analgesics, regionally and locally administered agents, routes and techniques of administration, non-pharmacological methods, specific clinical situations and specific patient groups.

Findings

There is a summary provided of the evidence at the beginning of the book. This is subsequently expanded upon throughout the guidelines.

Significance

This is the second version of the most complete source of current evidence, and is designed to have a 5-year shelf life before further review. Heitz WH, Witkowski TA and Viscusi ER (New and emerging analgesics and analgesic technologies for acute pain management) have produced a recent review of new techniques. (Current Opinion in Anaesthesiology. 2009; 22: 608–17). A large body of research focused on NSAIDs and COX-2 inhibitors has been retracted due to fraud (see editorial by White PF, Kehlet H, Liu S. Perioperative analgesia: What do we still know? Anesthesia and Analgesia. 2009; 108: 1364–7).

Rigg JR, Jamrozik K, Myles PS, et al (MASTER Anaesthesia Trial Study Group). Epidural anaesthesia and analgesia and outcome of major surgery: a randomised trial. Lancet. 2002; 359: 1276–82.

Methods

There were 915 patients randomised to epidural anaesthesia with general anaesthesia, or control. The primary end-point of the study was 30-day mortality or major surgical morbidity.

Findings

Eight categories of morbidity end-points were looked at. Only respiratory complications showed a significant reduction with epidural anaesthesia. Pain scores in the first 3 postoperative days were lower with regional anaesthesia and there were no major adverse effects of epidurals detected. There was no overall difference in mortality between the two groups.

Significance

The authors suggest that in major intra-abdominal surgery the combination use of general and regional anaesthesia has modest benefits, as stated above, without any major adverse effects. This finding was supported by a retrospective cohort study looked at 259,037 patients aged over 40 having intermediate to high-risk non-cardiac surgery. Survival was measured at 30 days. Twenty-two per cent of these patients received epidural anaesthesia. Within the matched pairs cohort there was a small mortality benefit at 30 days, which was felt to be of borderline significance (Wijeyesundera DN, Beattle WS, Austin PC, et al. Epidural anaesthesia and survival after intermediate-to-high risk non-cardiac surgery: a population-based cohort study. Lancet. 2008; 372: 562–9). This had led to a fall in epidural usage in Australia.

Horlocker TT, Wedel DJ, Benzon H, et al. Regional anesthesia in the anticoagulated patient: defining the risks (The Second ASRA Consensus Conference on Neuraxial Anesthesia and Anticoagulation). Regional Anesthesia and Pain Medicine. 2003; 28: 172–97.

Methods

This remains the definitive summary of timing of anticoagulation and placement/removal of regional anaesthesia associated with surgery.

The review covers current recommendations for the prevention and treatment of venous thromboembolism: risk of bleeding associated with antithrombotic and thrombolytic therapy and pharmacology of fractionated and unfractionated heparin, along with oral anticoagulants and antiplatelet agents.

Findings

The incidence of epidural and spinal haematoma respectively is less than 1 in 150,000 and 1 in 220,000 respectively. The INR should be less than 1.5 and antiplatelet agents should be ceased 7 days prior to surgery. Epidural catheters should be placed at least 1 hour after SC heparin and removed at least 2–4 hours after cessation of intravenous infusions of heparin. Epidural placement should occur at least 10–12 hours after dosing (for prophylaxis) and 24 hours if on a treatment dose of fractionated heparin.

Significance

The review provides guidelines but emphasises a patient-by-patient approach, taking into account other factors such as traumatic insertion, optimisation of coagulation status at insertion time and vigilant monitoring for neurological complications after insertion.

Renal medicine - Dialytic therapies

Bellomo R, Chapman M, Finfer S. et al. Low-dose dopamine in patients with early renal dysfunction: a placebo-controlled randomised trial. Australian and New Zealand Intensive care Society (ANZICS) Clinical Trials Group. Lancet 2000; 356: 2139–43.

Methods

Multicentre trial involving 328 patients randomised to receive a continuous low dose dopamine infusion (2 mcg/kg/min) or placebo via a central line while in ICU with evidence of SIRS and early acute renal dysfunction.

Findings

There was no difference in peak serum creatinine, requirements for renal replacement therapy, ICU or hospital length of stay.

Significance

The study helped eliminate the myth that dopamine has renal protective effects. It should not be forgotten that dopamine is a natriuretic agent that may increase renal perfusion through inotropic and vasopressor effects, although with complex dose-responses. This was also the first major achievement of the ANZICS Clinical Trials Group. Such collaborations are important if high-quality multicentre studies can be achieved.

Eknoyan G, Beck GJ, Cheung AK, et al. Hemodialysis (HEMO) Study Group. Effect of dialysis dose and membrane flux in maintenance hemodialysis. New England Journal of Medicine. 2002; 347: 2010–19.

Methods

Two by two factorial randomised trial comparing low-versus high-flux dialysers and dose of dialysis for haemodialysis patients having thrice-weekly treatments: standard equilibrated Kt/V 1.2 and urea reduction ratio approximately 65% compared with Kt/V 1.7 and urea reduction ratio 75%.

Findings

No difference in mortality during a mean follow-up of 3 years.

Significance

In chronic haemodialysis-dependent patients, high-flux dialysers or an increased dose of dialysis does not appear to make a difference to outcomes. It was unclear if this is also true for CRRT therapies in acute or chronic renal failure that prompted dosing studies in critically ill patients.

Bellomo R, Cass A, Cole L, et al. (RENAL Replacement Therapy Study Investigators). Intensity of continuous renal-replacement therapy in critically ill patients. New England Journal of Medicine. 2009; 361: 1627–38.

Methods

Multicentre, randomised study of 1508 ICU patients requiring CRRT (post-dilution CVVHDF) with ultrafiltration rates of 40 mL/kg/hr or 25 mL/kg/hr.

Findings

There was no difference in the primary outcome measure of 90-day mortality.

Significance

This study was prompted by a smaller single-centre trial of dosing of dialysis in the ICU (Ronco C, Bellomo R, Homel P, et al. Effects of different doses in continuous veno-venous haemofiltration on outcomes of acute renal failure: a prospective randomised trial. *Lancet*. 2000; 356: 26–30). This previous randomised controlled trial of 425 heterogeneous ICU patients with oliguric acute renal failure requiring CVVH, compared ultrafiltration rates of 20 versus 35 versus 45 mL/kg/hr. The end-point was survival 15 days after dialysis ceased. The study showed 35 and 45 mL/kg/hr are equivalent, and more effective than 20 mL/kg/hr. The implications of this more definitive study is that a lower dose of dialysis is acceptable, with lower costs and less need for dialysis fluid bag changes, reducing the labour required by nursing staff. The all-cause mortality rate in the study was also lower than traditionally described in international studies and over 90% of surviving patients recovered renal function within 90 days, including many with significant pre-existing chronic renal failure.

Vinsonneau C, Camus C, Combes A, et al. Continuous venovenous haemodiafiltration (CVVHDF) versus intermittent haemodialysis (IHD) for acute renal failure in patients with multiple-organ dysfunction syndrome: a multicentre randomised trial. Lancet 2006; 368: 379–85.

Methods

Prospective randomised study of 360 medical and surgical critically ill patients with acute renal failure as part of MODS comparing CVVHDF (continuous mean blood flow of 146 mL/min) and IHD (5 hours with mean blood flow of 278 mL/min).

Findings

There was no difference in the 60-day mortality between the groups with equivalent efficacy (mean urea concentrations and fluid removal). Importantly, IHD was not associated with an increased incidence of complications such as hypotension. CVVHDF did cause significantly more hypothermia. There was also no difference in the duration of renal support.

Significance

This challenges the notion of CRRT proponents that continuous techniques provide more haemodynamic stability and are always preferable in acutely ill patients with MODS. A Cochrane review (Rabindranath K, Adams J, Macleod AM, Muirhead N. Intermittent versus continuous renal replacement therapy for acute renal failure in adults. *Cochrane database Systematic Reviews*. 2007; 18: CD003773) also failed to show a mortality difference, but there was a higher mean arterial pressure in patients on CRRT. They also concluded that newer hybrid therapies (e.g. slow low efficiency dialysis) warrant further evaluation. Since this review, varying intensities of CVVH or SLED (in haemodynamically unstable patients) and IHD (in haemodynamically stable patients) have been studied and no difference found in mortality or rates of renal recovery (Palevsky PM, Zhang JH, O'Connor TZ, et al. VA/NIH Acute Renal failure Trial Network. Intensity of renal support in critically ill patients with acute kidney injury. *New*

England Journal of Medicine. 2008; 359: 7–20). Ongoing controversies in renal critical care medicine pertain to factors such as the timing of commencing renal replacement therapies, modes of anticoagulation to prevent circuit clotting and optimal membrane composition.

Renal medicine - Prevention of radiocontrast nephropathy

Solomon R, Werner C, Mann D, et al. Effects of saline, mannitol, and furosemide to prevent acute decreases in renal function induced by radiocontrast agents. New England Journal of Medicine. 1994; 331: 1416–20.

Methods

Randomised trial of 78 patients with chronic renal failure undergoing coronary angiography with ionic contrast. The patients received intravenous .45% saline 12 hours before and after the study, saline plus 25 g mannitol or saline plus furosemide (80 mg).

Findings

The least increase in creatinine was with the saline alone and greatest increase was in the furosemide group.

Significance

The concept of fluid loading before giving intravenous contrast was cemented with this article, although it was in non-critically ill patients. More recent studies reveal that normal saline hydration is superior to .45% saline and hydration remains the mainstay of prevention.

Tepel M, van der Giet M, Schwarzfeld C, et al. Prevention of radiographic-contrast-agent-induced reductions in renal function by acetylcysteine. New England Journal of Medicine. 2000; 343: 210–12.

Methods

Randomised study of 83 patients with chronic renal insufficiency of N-acetyl cysteine (600 mg orally twice daily with 2 doses before and 2 after the non-ionic contrast study) plus .45% saline infusion (1 mL/kg/hr 12 hours before and after) versus fluid protocol alone.

Findings

Non-significant rise in creatinine in the control group and a significant reduction in creatinine in the N-acetyl cysteine group at 48 hours.

Significance

The results may not be directly relevant to critically ill patients or in acute renal failure and an ideal dosing regimen (e.g. for intravenous administration) is unclear. Subsequent studies have had conflicting results and a systematic review has suggested a trend to benefit (Alonso A, Lau J, Javer BL, et al. Prevention of radiocontrast nephropathy with N-acetylcysteine in patients with chronic kidney disease: a meta-analysis of randomized, controlled trials. American Journal of Kidney Disease. 2004; 43: 1–9). Further studies are needed in the ICU population. Some units use the same intravenous regimen as for paracetamol poisoning when the enteral regimen is not appropriate.

Marenzi G, Marana I, Lauri G, et al. The prevention of radiocontrast-agent-induced nephropathy by hemofiltration. New England Journal of Medicine. 2003; 349: 1333–40.

Methods

Randomised, controlled trial of 114 patients with chronic renal failure undergoing percutaneous coronary

interventions. Patients received isotonic saline hydration (1 mL/kg/hr) or haemofiltration (1 L/hr replacement without fluid removal) from 4–8 hours before to 18–24 hours after the procedure.

Findings

Significantly fewer patients treated with haemofiltration had a 25% increase in serum creatinine and requirement for temporary renal replacement therapy. A reduction in in-hospital and 1-year mortality was also found.

Significance

The same group went on to show that pre- and post-contrast haemofiltration is even more beneficial than post-exposure haemofiltration alone in a study involving 92 similar patients randomised to receive the same hydration protocol, the same haemofiltration protocol or a new study arm who received 12 hours of the hydration protocol then only post-procedure haemofiltration for 18–24 hours (American Journal of Medicine. 2006; 119: 155–62). A systematic review examining different forms of extracorporeal blood purification therapies for prevention of contrast injury, however, suggested no benefit, although there was high inter-trial heterogeneity (Cruz DN, Perazella MA, Bellomo R, et al. Extracorporeal blood purification therapies for prevention of radiocontrast-induced nephropathy: a systematic review. American Journal of Kidney Diseases. 2006; 48: 361–71). It is unclear if there is a benefit in critically ill patients and it may be inferred that ICU patients who already have vascular access for renal replacement therapy, who require contrast studies, may benefit from haemofiltration peri-procedurally, although further studies are needed.

Merten GJ, Burgess WP, Gray LV, et al. Prevention of contrast-induced nephropathy with sodium bicarbonate: a randomised controlled trial. JAMA 2004; 291: 2328–34.

Methods

Randomised trial of 119 patients with chronic renal failure. They received 154 meq/L of normal saline or sodium bicarbonate as a bolus 1 hour before, followed by a 6-hour infusion after, non-ionic intravenous contrast.

Findings

There was a significant reduction in onset of nephropathy (defined as a 25% increase in creatinine within 2 days) with bicarbonate.

Significance

This is an attractive option, as benefit is shown with only a 1-hour preparation time, which is appealing for critically ill patients requiring emergency imaging. Similar to the other studies on prevention of radio-contrast injury, this study was also in non-ICU patients and involved a single centre. A number of studies of bicarbonate therapy followed and a systematic review (Zoungas S, Ninomiya T, Huxley R, et al. Systematic review: sodium bicarbonate treatment regimens for the prevention of contrast-induced nephropathy. Annals of Internal Medicine. 2009; 151: 631–8) showed heterogeneity in outcomes, with benefit more likely with lower quality studies. Large multicentre studies are still needed that preferably compare various agents including other promising therapies such as theophylline. A single-centre study comparing three regimens failed to show a benefit of sodium bicarbonate or N-acetylcysteine over hydration with sodium chloride alone (Ozcan EE, Guneri S, Akdeniz B, et al. Sodium bicarbonate, N-acetylcysteine, and saline for prevention of radiocontrast-induced nephropathy. A comparison of three regimens for protecting contrast-induced nephropathy in patients undergoing coronary procedures. A single-center prospective controlled trial. American Heart Journal. 2007;154: 539–44).

Respiratory medicine - ARDS

Amato MB, Barbas CS, Medeiros DM, et al. Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. *New England Journal of Medicine*. 1998; 338: 347–54.

Methods

Single-centre study involving 53 patients with ARDS randomised to conventional ventilation (lowest PEEP that maintained acceptable oxygenation with tidal volumes of 12 mL/kg and normal PaCO₂) with a 'protective strategy' (PEEP above the lower inflection point on the static pressure-volume curve, tidal volumes of 6 mL/kg with driving inspiratory pressures of less than 20 cmH₂O above the PEEP and permissive hypercapnoea).

Findings

There was a significant reduction in 28-day but not in-hospital mortality. The incidence of significant barotrauma and duration of mechanical ventilation were reduced.

Significance

Around this time several other studies evaluated 'protective ventilation' using low tidal volumes with negative results. All of these studies suffered from low numbers.

The Acute Respiratory Distress Syndrome Network. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *New England Journal of Medicine*. 2000; 342: 1301–8.

Methods

Multicentre randomised trial involving 861 patients with ARDS comparing tidal volumes of 12 mL/kg (with plateau pressures of 50 cmH₂O or less) with 6 mL/kg (with plateau pressures of 30 cmH₂O or less).

Findings

There was a significant reduction in duration of mechanical ventilation and in-hospital mortality in the low tidal volume group. The mean PEEP in the low tidal volume group was 8 cmH₂O and mean respiratory rate was 28. In the high tidal volume group a mean PEEP of 9 cmH₂O was applied with a respiratory rate of 19.

Significance

This article provided strong evidence favouring the low tidal volume 'protective ventilation strategy' and the use of low tidal volumes combined with increased PEEP has become a conventional ventilatory strategy for conditions producing poor lung compliance.

The major criticism of articles such as Amato and ARDS net, compared to those that found negative results, is that low tidal volumes were compared with very high tidal volumes, which have been felt for many years to be injurious and thus did not reflect conventional ventilatory management. The contribution of PEEP and autoPEEP to the results are also unclear.

Oba Y, Thameem DM, Zaza T. High levels of PEEP may improve survival in acute respiratory distress syndrome: a meta-analysis. *Respiratory Medicine*. 2009; 103: 1174–81.

Methods

Meta-analysis of five studies enrolling 2447 patients where different strategies for PEEP, as part of critically ill patients ventilatory management, were compared.

Findings

They found a significant reduction in hospital mortality in favour of high PEEP. Statistical and clinical heterogeneity, including differences in disease severity and ventilator protocols, were important confounding issues. For example, one of the larger, higher quality studies suggested that high PEEP was not superior to lower PEEP for patients with ARDS or acute lung injury who received mechanical ventilation with a tidal volume of 6 mL/kg and end-inspiratory plateau pressure limit of 30 cmH₂O (Brower RG, Lanken PN, MacIntyre N, et al. National Heart, Lung, and Blood Institute ARDS Clinical Trials network. *New England Journal of Medicine*. 2004; 35: 327–36).

Significance

It remains unclear if PEEP has an independent mortality benefit in ARDS. The best methods of titrating PEEP and how to determine 'optimal' remains one of intensive care medicine's greatest controversies. Every year new papers are added.

Meduri GU, Headley AS, Golden E, et al. Effect of prolonged methylprednisolone therapy in unresolving acute respiratory distress syndrome: a randomized controlled trial. *JAMA*. 1998; 280: 159–65.

Methods

Randomised, double-blind, placebo-controlled trial of 24 patients with severe ARDS who failed to improve by the seventh day of respiratory failure. Patients received either methylprednisolone (2 mg/kg in 4 divided doses for 2 weeks, followed by a 2-week taper) or placebo.

Findings

They reported a significant reduction in ICU mortality, oxygenation and MODS score.

Significance

The small numbers of patients and differences in baseline characteristics between the groups made the study interesting but prompted further investigation. More recently, a trial involving 180 patients with ARDS, randomised between 7 and 28 days after the onset of lung disease, received placebo or methylprednisolone (2 mg, then 0.5 mg/kg every 6 hours for 14 days, followed by the same dose twice daily, then a tapering dose over 4–21 days). There was no significant difference between the groups for the primary end-point of 60-day mortality. Another finding was an increase in deaths of patients commenced on steroids more than 2 weeks after the onset of ARDS. Importantly, there was no increase in the incidence of nosocomial infections for the steroid group and only a non-significant trend to more cases of neuromyopathy.

The ARDS Clinical Trials Network. Efficacy and safety of corticosteroids for persistent acute respiratory distress syndrome. *New England Journal of Medicine*. 2006; 354: 1671–84.

Methods

This multicentre, randomised, double-blind, placebo-controlled trial recruited 180 patients with ARDS of at least 7 days duration.

Findings

There was no beneficial effect on hospital survival. Furthermore, initiating treatment with methylprednisolone 2 or more weeks after the onset of ARDS was associated with significantly increased mortality at 60 and 180 days, as compared with the placebo group. Methylprednisolone was associated with an increased number of ventilator-free and shock-free days during the first 28 days, in association with an improvement in oxygenation, respiratory compliance and blood pressure, with fewer days of vasopressor therapy. Methylprednisolone did not increase the

rate of infectious complications compared to the placebo group, but was associated with a higher rate of neuromuscular weakness.

Significance

These results do not support the routine use of methylprednisolone for persistent ARDS, despite the improvement in cardiopulmonary physiology. There may be an as yet undefined role for steroids, but it is unclear what the best timing is. A meta-analysis was also unable to show convincing evidence in either prevention of or improvement in established ARDS (Peter JV, Graham PL, Moran JL, George IA, Bersten A. Corticosteroids in the prevention and treatment of acute respiratory distress syndrome (ARDS) in adults: meta-analysis. *BMJ*. 2008; 336: 1006–9).

Gattinoni L, Tognoni G, Pesenti A, et al. Effect of prone positioning on the survival of patients with acute respiratory failure. *New England Journal of Medicine*. 2001; 345: 568–73.

Methods

Multicentre randomised trial of 304 patients with acute lung injury or ARDS comparing supine positioning with 10 days of prone positioning (at least 6 hours per day).

Findings

Improvements in oxygenation were demonstrated, but not survival.

Significance

There was no increase in the incidence of complications, such as accidental extubation, associated with prone positioning. This remains a dreaded potential problem, particularly in patients with the most severe impairments in gas exchange. The lack of a positive benefit may have been due to the heterogeneous nature of the patients included, with the study not sufficiently powered to detect an effect in the sickest of individuals. It is also more difficult to achieve safely in obese patients. This was followed by further negative multicentre, randomised trials. Most recently, in 342 patients with ARDS and moderate and severe hypoxaemia, proning did not improve the 28-day or 6-month mortality and there were increased complications in the proned group (Taccone P, Pesenti A, Latini R, et al. Prone positioning in patients with moderate and severe acute respiratory distress syndrome: a randomized controlled trial. *JAMA*. 2009; 302: 1977–984.

Taylor RW, Zimmerman JL, Dellinger RP, et al. Low-dose inhaled nitric oxide in patients with acute lung injury: a randomized controlled trial. *JAMA*. 2004; 291: 1603–9.

Methods

Multicentre, randomised trial of 385 patients with ARDS comparing 5 ppm of nitric oxide with placebo. Significant exclusion criteria were sepsis as the aetiology of ARDS and non-pulmonary organ system dysfunction.

Findings

There was no reduction in mortality or the duration of mechanical ventilation. There was a significant increase in PaO₂. These findings are consistent with other studies.

Significance

A subsequent meta-analysis also failed to show a mortality benefit or reduction in duration of ventilation. Improvements in oxygenation were noted (Adhikari NK, Burns KE, Freidrich JO, et al. Effect of nitric oxide on oxygenation and mortality in acute lung injury: systematic review and meta-analysis. *BMJ*. 2007; 334: 779–86). The

lack of a mortality benefit may be related to insufficient power to detect an effect in the sickest of patients or reflect an insufficient dose of nitric oxide.

The threshold to deliver nitric oxide remains an individual clinician decision, although many would agree there is a role in ARDS with severe hypoxaemia refractory to other interventions. It is expensive to deliver and for this reason other selective pulmonary vasodilators, such as inhaled prostacycline, are being explored. Unfortunately, the evidence for them is equally poor.

National Heart, lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network. Comparison of two fluid-management strategies in acute lung injury. New England Journal of Medicine. 2006; 354: 2564–75.

Methods

Randomised study involving 1000 patients with acute lung injury who received a conservative or liberal fluid strategy guided either by a central venous line or a pulmonary artery catheter. Detailed algorithms were prescribed for patients in each of four groups to guide management (e.g. interventions included fluid boluses, diuretics and vasoactive infusions to achieve a central venous pressure (CVP) of 10–14 mmHg or pulmonary artery occlusion pressure (PAOP) 14–18 mmHg in the liberal strategy groups and CVP less than 4 mmHg and PAOP less than 8 in the conservative strategy).

Findings

There was no difference in 60-day mortality between the groups, although there were improved indices of respiratory function and reduced duration of mechanical ventilation without an increase in non-pulmonary organ failures.

Significance

Concerns have been raised about the high exclusion rate, with less than 10% of screened patients being randomised to the study. Algorithm-driven therapy was also started after a lag time (e.g. on average 24 hours after establishment of acute lung injury). It remains unanswered whether benefit may be obtained from an early liberal, and later conservative approach to fluid therapy, as the systemic inflammatory response peaks then resolves.

Derdak S, Mehta S, Stewart TE, et al. (Multicentre Oscillatory Ventilation for Acute Respiratory Distress Syndrome (MOAT) Study Investigators). High-frequency oscillatory ventilation (HFOV) for acute respiratory distress syndrome in adults: a randomized, controlled trial. American Journal of Respiratory and Critical Care Medicine. 2002; 166: 801–8.

Methods

Multicentre, randomised, controlled trial comparing the safety and effectiveness of HFOV with conventional ventilation.

Findings

There was no difference in 30-day mortality, haemodynamic variables, oxygenation or ventilation failure, barotrauma or mucus plugging.

Significance

This is one of the first studies that evaluated HFOV. Ongoing high-quality studies (e.g. OSCAR trial) are evaluating HFOV as an alternative to conventional ventilation. It also needs to be evaluated as a rescue method. Although a recent systematic review was criticised because it included studies with relatively small patient numbers, cross-over

from assigned groups and wide confidence intervals, it concluded that there may be a mortality benefit (Sud S, Sud M, Friedrich JO, et al. BMJ. 2010; 340:doi:10.1136/bmj.c2327).

Peek GJ, Mugford M, Tiruvoipati R, et al (CESAR trial collaboration). Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. Lancet. 2009; 374: 1351–63.

Methods

Multicentre, randomised trial assigning 180 adults with severe but potentially reversible respiratory failure to receive continued conventional management or referral for consideration of ECMO.

Findings

Only 68 patients actually received VV (venovenous) ECMO. Significantly more patients allocated to the ECMO group (63% vs 47% of those in the conventional therapy group) survived to 6 months without disability.

Significance

The authors concluded that patients with severe potentially reversible respiratory failure should be referred to an ECMO centre. The 2009 H1N1 influenza pandemic saw large numbers of patients with acute respiratory failure survive with the aid of ECMO (The Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators. Extracorporeal Membrane Oxygenation for 2009 Influenza A (H1N1) Acute Respiratory Distress Syndrome. JAMA. 2009; 302: 1888–95), although there is much debate generated regarding the relative benefit of this therapy over other rescue therapies when conventional ventilatory strategies fail. High-frequency oscillatory ventilation is one such therapy that is gaining in popularity, but has not been compared directly with ECMO. It offers benefits of being less invasive and avoids the need for anticoagulation. Other novel therapies, such as those offering CO₂ removal, need further evaluation.

Respiratory medicine - Non-invasive ventilation

Plant P, Owen J, Elliott M. Early use of non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease on general respiratory wards: a multicentre randomized controlled trial. Lancet. 2000; 355: 1931–5.

Methods

This multicentre, randomised controlled study involved 236 patients with acute hypercapnoeic exacerbations of COPD with mild to moderate respiratory acidosis.

Findings

There was a reduced need for intubation and lower in-hospital mortality in the group that received non-invasive ventilation on a respiratory ward.

Significance

This was one of the first quality studies demonstrating a clear benefit of non-invasive ventilation in this patient group. This was confirmed in a systematic review that identified eight studies that compared non-invasive positive pressure ventilation and standard care with standard care alone in patients with hypercapnic respiratory failure from an exacerbation of COPD (Lightowler JV, Wedzicha JA, Elliott MW, Ram FS. Non-invasive positive pressure ventilation to treat respiratory failure resulting from exacerbations of chronic obstructive pulmonary disease: Cochrane systematic review and meta-analysis. BMJ. 2003; 326: 185).

Masip J, Roque M, Sanchez B, et al. Non-invasive ventilation in acute cardiogenic pulmonary edema. JAMA. 2005; 294: 3124–30.

Methods

Systematic review with quantitative analysis of 15 trials of patients with acute cardiogenic pulmonary oedema comparing non-invasive ventilation (CPAP - continuous positive airway pressure and BIPAP – bilevel positive pressure ventilation) with conventional oxygen therapy.

Findings

They found a significant reduction in mortality for CPAP and need for intubation. Remaining doubt regarding the effects on mortality with BIPAP remained, due to the small numbers of studies involved.

Significance

This was one of the studies using BIPAP (Mehta S, Jay GD, Woolard RH. Randomized, prospective trial of bilevel versus continuous positive airway pressure in acute pulmonary oedema. *Critical Care Medicine*. 1997; 25: 620–8).

This trial was prematurely terminated after recruiting only 27 patients because of an increased incidence of myocardial infarction in the BIPAP group. Importantly, the groups were unmatched with an increased number of patients with chest pain at entry into the study randomised to the BIPAP group.

Other indications for non-invasive ventilation, with less compelling evidence based on small studies, include pneumonia in immunosuppressed patients and, to a lesser extent, isolated chest trauma with rib fractures (in association with regional analgesia), acute-on-chronic hypercapnoeic respiratory failure due to chest wall deformity or neuromuscular disease and arguably exacerbations of asthma.

Respiratory medicine - Nosocomial pneumonia

Drakulovic MB, Torres A, Bauer TT, et al. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomised trial. Lancet. 1999; 354: 1851–8.

Methods

This randomised study involved 86 intubated and mechanically ventilated patients in 2 ICUs in a single centre, who were nursed either in the supine or semi-recumbent position. The premise was that gastro-oesophageal reflux, micro-aspiration and nosocomial pneumonia would be reduced if patients were not lying flat.

Findings

The study was stopped at an interim analysis that showed a significant reduction in nosocomial pneumonia in the semi-recumbent patients. Supine position and enteral nutrition were independent risk factors for pneumonia.

Significance

This is a simple no-cost intervention that may have significant benefits for all critically ill patients. There have been a myriad of studies that have tried to look at various preventative strategies. Handwashing, especially using alcohol-based hand-rubs, and possibly endotracheal tubes permitting continuous sub-glottic suctioning have been shown to reduce the incidence of nosocomial pneumonia. In-line suctioning devices have not been convincingly shown to make a difference. Head elevation is a key element of bundles (e.g. ventilation bundle) and part of the FASTHUG mnemonic.

Fagon JY, Chastre J, Wolff M, et al. Invasive and noninvasive strategies for management of suspected ventilator-associated pneumonia. A randomized trial. *Annals of Internal Medicine*. 2000; 132: 621–30.

Methods

Multicentre study involving 413 patients with suspected ventilator-associated pneumonia. Patients were randomised to have an invasive management strategy (direct examination of bronchoscopic protected brush samples or bronchoalveolar lavage samples and their quantitative cultures with cessation of empirical antibiotics if negative examination) or clinical management based on clinical criteria, isolation of organisms by non-quantitative analysis of endotracheal aspirates and empirical antibiotic treatment.

Findings

The invasive group had a significantly reduced 14- and 28-day mortality and reduced antibiotic use.

Significance

It is unclear if the additional costs and risks of the invasive strategy justify the routine use of this approach, and if there are longer-term benefits. A subsequent randomised trial of diagnostic techniques for VAP in 740 immunocompetent patients found no difference between quantitative culture of bronchoalveolar lavage fluid and endotracheal aspirates in patients with VAP (The Canadian Critical Care Trials Group. A randomized trial of diagnostic techniques for ventilator-associated pneumonia. *New England Journal of Medicine*. 2006; 355: 2619–30). Bronchoscopy seems most appropriate in complicated patients (e.g. immunosuppressed patients and those not responding to conventional therapy). Guidelines for management of adults with hospital-acquired, ventilator-associated and healthcare-associated pneumonia address this as well as a wealth of other issues (American Thoracic Society; Infectious Diseases Society of America. *American Journal of Respiratory and Critical Care Medicine*. 2005; 171: 388–416).

Respiratory medicine - Thromboembolism

Quinlan D, McQuillan A, Eikelboom J. Low-molecular-weight heparin compared with intravenous unfractionated heparin for treatment of pulmonary embolism: a meta-analysis of randomized, controlled trials. *Annals of Internal Medicine*. 2004; 140: 175–83.

Methods

This study analysed 12 trials involving 2110 patients treated for symptomatic or asymptomatic non-massive pulmonary embolism.

Findings

Compared with unfractionated heparin, low-molecular-weight heparin was associated with a non-statistically significant decrease in recurrent symptomatic venous thromboembolism at the end of treatment and at 3 months without a significant increase in bleeding complications.

Significance

Low-molecular-weight heparin may safely replace unfractionated heparin for acute treatment of non-massive pulmonary embolism. The suitability of this approach needs to be determined for individual patients as dosing of LMW heparin can be unpredictable (e.g. renal failure and elderly patients).

Konstantinides S, Geibel A, Heusel G, et al. Management Strategies and Prognosis of Pulmonary Embolism-3 Trial Investigators. Heparin plus alteplase compared with heparin alone in patients with submassive pulmonary embolism. New England Journal of Medicine. 2002; 347: 1143–50.

Methods

Double-blind, randomised trial of 256 patients with acute pulmonary embolism and pulmonary hypertension or right ventricular dysfunction, but without arterial hypotension or shock. Patients received either heparin plus 100 mg alteplase or heparin plus placebo over 2 hours.

Findings

There was a significant reduction of in-hospital mortality in the group receiving thrombolysis with a reduced need for interventions (e.g. CPR, emergency surgical embolectomy or catheter thrombosis fragmentation). No fatal bleeding or cerebral bleeding occurred in the lysis group.

Significance

There is a general consensus that lysis is appropriate for patients with massive pulmonary emboli presenting with overt right heart failure and cardiogenic shock, although the relative benefit of thrombolysis over mechanical therapies (e.g. clot maceration, thoracotomy with embolectomy) is unclear. This study added to the literature supporting a safe role for submassive pulmonary embolism.

Curzio KM, Cheng-Lai A, Kheifets V, et al. A comparison of direct thrombin inhibitors in the treatment of heparin-induced thrombocytopenia (HIT): a single institution experience. Journal of Thrombosis and Thrombolysis. 2009; 28: 117–23.

Methods

Retrospective study to compare the effects of lepirudin and argatroban in the management of HIT in 82 patients.

Findings

Thrombin inhibitors improve the morbidity and mortality relating to HIT but there was no significance difference found between the two agents.

Significance

A range of options exist for treating HIT, including danaparoid (heparinoid), the direct thrombin inhibitors (e.g. lepirudin, bivalirudin, argatroban) and fondaparinux. While studies exist demonstrating utility of these agents in HIT, studies such as this co

Respiratory medicine - Weaning

Brochard L, Rauss A, Benito S, et al. Comparison of three methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation. American Journal of Respiratory and Critical Care Medicine. 1994; 150: 896–903.

Methods

Randomised study in three ICUs involving 109 mechanically ventilated patients deemed ready for weaning. Those who failed to sustain 2 hours of a T-piece trial were randomised to synchronised intermittent mandatory ventilation (SIMV), pressure support ventilation (PSV) or further T-piece sessions.

Findings

There was a significant increase in the number of patients weaned successfully at 21 days with PSV.

Significance

In contrast, a similar study (Esteban A, Frutos F, Tobin MJ, et al. A comparison of four methods of weaning patients from mechanical ventilation. *New England Journal of Medicine*. 1995; 332: 345–50) found that a once-daily spontaneous breathing trial was equally as effective as multiple daily trials and led to extubation three times more rapidly than SIMV, and twice as quickly as PSV. Both papers concur that weaning the SIMV rate is the least effective weaning method. Local practices with regards to preferred weaning modalities vary widely.

Nava S, Gregoretti C, Fanfulla F, et al. Non-invasive ventilation to prevent respiratory failure after extubation in high-risk patients. *Critical Care Medicine*. 2005; 33: 2465–70.

Methods

Multicentre, randomised controlled study of 97 patients requiring more than 48 hours of mechanical ventilation considered at risk of developing postextubation respiratory failure (including patients with hypercapnoea, congestive heart failure, weak cough and excessive secretions, multiple co-morbidities, upper airway obstruction). Patients were extubated to non-invasive ventilation for at least 8 hours or oxygen.

Findings

A significant reduction in the rate of reintubation was found with non-invasive ventilation.

Significance

This study supported others of its kind identifying a role of *electively* extubating to non-invasive ventilation. This is distinct from non-invasive ventilation as a rescue therapy for post-extubation respiratory failure, which in unselected patients has been shown to be ineffective (Esteban A, Frutos-Vivar F, Ferguson ND, et al. Noninvasive positive-pressure ventilation for respiratory failure after extubation. *New England Journal of Medicine*. 2004; 350: 2452–60). Further studies have followed such that a systematic review has subsequently concluded a benefit of this approach on mortality and incidence of ventilator-associated pneumonia in patients with chronic obstructive pulmonary disease (Burns KE, Adhikari NK, Keenan SP, Meade M. Use of non-invasive ventilation to wean critically ill adults off invasive ventilation: meta-analysis and systematic review. *BMJ*. 2009; 338: b1574).

Comparing their relative merits are lacking

Respiratory medicine - Other issues

Akinnuse ME, Pineda LA, El Solh AA. Effect of obesity on intensive care morbidity and mortality: a meta-analysis. *Critical Care Medicine*. 2008; 36: 151–8.

Methods

Meta-analysis of 14 studies involving 15,347 subjects, comparing outcomes in obese and non-obese critically ill patients in intensive care settings.

Findings

Obesity is not associated with excess mortality, but is significantly related to prolonged duration of mechanical ventilation and ICU length of stay.

Significance

Bariatric patients are increasingly encountered in ICUs, either requiring management of their obesity-related or

unrelated complications, or preoperative bariatric or non-bariatric surgery support. This study has great relevance for resource planning, as well as for informing expectations for individual patients.

Griffiths J, Barber VS, Morgan L, Young JD. Systematic review and meta-analysis of the timing of tracheostomy in adult patients undergoing artificial ventilation. BMJ. 2005; 330: 1243–7.

Methods

Well-conducted, systematic review looking at randomised and quasi-randomised controlled studies that compared early tracheostomy with either later tracheostomy or prolonged endotracheal intubation. From 15,950 articles screened, 5 papers were analysed involving 406 patients.

Findings

They found no difference in mortality or the risk of pneumonia. There was, however, a significant reduction in the duration of artificial ventilation and ICU length of stay.

Significance

The number of studies was more limited than expected and the importance of new large studies underscored. The results of the TracMan study have been reported. This large, multicentre, randomised trial compared early tracheostomy (day 1–4) with late tracheostomy (after day 10) and found no difference in 30-day mortality. Interestingly, only 45% of patients allocated to the late group actually received a tracheostomy, reflecting the poor recruitment due possibly to strongly held beliefs about existing practices.

Colebourn CL, Barber V, Young JD. Use of helium-oxygen mixture in adult patients presenting with exacerbations of asthma and chronic obstructive pulmonary disease: a systematic review. Anaesthesia. 2007; 62: 34–42.

Methods

Systematic review of 14 controlled and cross-over randomised trials of patients with an exacerbation of airways disease evaluating the effect of Heliox.

Findings

In asthma patients, Heliox-driven nebulisers slightly improve airflow measures. In patients with chronic obstructive airways disease receiving non-invasive ventilation, there was no change in CO₂ tension or respiratory rate; intubated patients demonstrated a reduced intrinsic PEEP.

Significance

The studies were of limited size and quality and the role of helium–oxygen mixtures remain unclear. Helium, by virtue of its lower density, may replace nitrogen and reduce the work of breathing required for respiration. The mixtures can be difficult to administer in ventilated patients and the combinations may have insufficient oxygen concentrations to meet the needs of patients.

Resuscitation and cardiac arrest

Bernard SA, Gray TW, Buist MD, et al. Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. New England Journal of Medicine. 2002; 346: 557–63.

Methods

Randomised controlled trial involving 77 patients who remained unconscious after resuscitation from out-of-hospital cardiac arrest due to ventricular fibrillation. The hypothermia group were cooled to 33°C within 2 hours and maintained for 12 hours.

Findings

There was a significant improvement in the neurological outcomes of the hypothermia group, with more cooled patients being discharged home or to a rehabilitation facility.

Significance

The result was consistent with the findings of the Hypothermia after Cardiac Arrest Study Group (New England Journal of Medicine. 2002; 346: 549–56). This multicentre study involved 136 patients with the hypothermia group cooled to 32–34°C for 24 hours, within 4 hours. Entry criteria included arrests due to ventricular fibrillation or non-perfusing ventricular tachycardia. Neither study demonstrated significant increases in complications and cooling has become a widespread intervention in post cardiac arrest patients. Unanswered questions include the best method of cooling, mode of rewarming (active vs passive) and monitoring devices for core temperature. The ideal duration of cooling, applicability to other types of cardiac arrest and influence on the timing of prognostication for hypoxic–ischaemic brain injury is unclear.

Hillman K, Chen J, Cretikos M, et al. MERIT study investigators. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. Lancet. 2005; 365: 2091–7.

Methods

The investigators randomised 23 Australian hospitals to function as usual or introduce a MET system. The MET call criteria consisted of disorders of breathing (respiratory rate <5 or >36 or arrest), circulation (HR <40 or >140 beats/min, systolic BP <90 or arrest), neurology (sudden fall in GCS >2 points, repeated or prolonged seizures) or 'serious worry' about any individual.

Findings

They found that the MET system greatly increases emergency team calling, but does not substantially affect the incidence of cardiac arrest, unplanned ICU admissions, or unexpected death.

Significance

This is the largest well-conducted study, but may still have been underpowered to detect a difference. There was also an underutilisation of the MET call criteria, despite a higher rate of calls than in the control centres. There may also be other less tangible benefits of MET teams that were not measured (e.g. end-of-life care, patients' and staff satisfaction). Previous studies, using before and after models, showed a more impressive difference; however, these were also single-centre studies.

The International Liaison Committee on Resuscitation. Circulation 2010; 122; 16: Supplement 2.

Methods

Evidence-based international expert consensus on issues relating to basic and advanced life support. The entire supplement is devoted to updating the ILCOR 2005 guidelines.

Findings

Relatively minor new changes were recommended, including factors to simplify the algorithm, promote lay-person

effectiveness (e.g. de-emphasis of ventilation), reduce interruptions to chest compressions and improve post-resuscitation care, including therapeutic hypothermia. Some changes to drug therapy were made, such as not administering atropine for asystole. In contrast, there were some major changes in the 2005 guidelines. In summary, the breath-to-compression ratio changed to two breaths for every 30 compressions, with 100 compressions per minute for any number of rescuers and for all people with cardiac arrests – adults and children (excluding neonates). Unless the cardiac arrest is witnessed, 'stacked' DC cardioversion with three shocks given before commencing CPR was no longer recommended and one shock only was advised. In all subsequent cycles of CPR requiring defibrillation, only one shock was recommended before continuing CPR, with 2 minutes of CPR to be given between attempts at defibrillation. All shocks were recommended to be 360 J with monophasic defibrillators, and 200 J for biphasic defibrillators. Review of previous iterations reveals factors such as the introduction of the Hs and Ts as an aide memoir to reversible causes of cardiac arrest and simplification of the ALS algorithm from three to two pathways.

Significance

Resuscitation councils in different countries have produced local ratified versions of these recommendations (e.g. British, European and Australian Resuscitation Councils). These vary slightly according to local practices and needs.

Dorian P, Cass D, Schwartz B, et al. Amiodarone as compared with lidocaine for shock-refractory ventricular fibrillation. *New England Journal of Medicine*. 2002; 346: 884–90.

Methods

Canadian randomised pre-hospital trial involving 347 patients with out-of-hospital VF resistant to three initial shocks, intravenous adrenaline and a further shock or had recurrent VF after initial successful defibrillation. Patients received either amiodarone (5 mg/kg) or lignocaine (1.5 mg/kg) and a second dose if VF persisted (amiodarone 2.5 mg/kg or lignocaine 1.5 mg/kg).

Findings

Significantly higher rates of survival to hospital admission were found with amiodarone (22.8% vs 12%). There was unfortunately no statistically significant difference in rates of survival to hospital discharge, although the study was not adequately powered to detect this.

Significance

Prior to this article lidocaine (lignocaine) was the first-line recommended drug therapy for VF refractory to defibrillation.

Wenzel V, Krismer AC, Arntz HR, et al. A comparison of vasopressin and epinephrine for out-of-hospital cardiopulmonary resuscitation. *New England Journal of Medicine*. 2004; 350: 105–13.

Methods

Triple-blinded, multicentre, randomised trial involving 1219 patients on vasopressin (40 IU) or epinephrine (1 mg) during out-of-hospital cardiorespiratory, followed by additional treatments with epinephrine as required.

Findings

Rates of hospital admission were the same for both regimens in patients with ventricular fibrillation or pulseless electrical activity. There was a higher survival to hospital admission for patients resuscitated with vasopressin from asystole.

Significance

It is unclear if vasopressin produces more neurologically injured survivors of asystole. A larger study also failed to show a benefit of combination therapy with a negative effect on survival in patients with PEA (Gueugniaud PY, David JS, Chanzy E, et al. Vasopressin and epinephrine vs. epinephrine alone in cardiopulmonary resuscitation. *New England Journal of Medicine*. 2008; 359: 21–30). A potential benefit may exist with this combination increasing the number of patients surviving to hospital who may be potential organ donors. This is an ethically controversial issue.

Sedation

Kress JP, Pohlman AS, Connor MF, Hall JB. Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. *New England Journal of Medicine*. 2000; 342: 1471–7.

Methods

Single-centre, randomised controlled trial of 128 mechanically ventilated medical ICU patients receiving continuous sedative infusions. The sedative infusions were either interrupted daily until the patient was awake or only at the discretion of the treating clinicians.

Findings

There was a reduction in the duration of mechanical ventilation and length of ICU stay.

Significance

In a subsequent article, the same group found that daily interruption of sedative infusions does not result in adverse psychological sequelae and reduces symptoms of post-traumatic stress disorder (PTSD) (*American Journal of Respiratory and Critical Care Medicine*. 2003; 168: 1457–61). Excess sedation has been associated with PTSD and thought to be related to delusional memories regarding events in the ICU (Jones C, Griffiths RD, Humphris G, Skirrow PM. Memory, delusions, and the development of acute posttraumatic stress disorder-related symptoms after intensive care. *Critical Care Medicine*. 2001; 29: 573–80). ICU-related PTSD is an interesting and ongoing area of research.

The potential benefits of avoiding excess sedation (e.g. reduced vasoactive drug therapy and fluid administration, reduced duration of mechanical ventilation and reduced ICU length of stay) were also highlighted and have stimulated many studies in this area.

Sessler CN, Gosnell MS, Grap MJ, et al. The Richmond Agitation-Sedation Scale: Validity and reliability in adult intensive care unit patients. *American Journal of Respiratory and Critical Care Medicine*. 2002; 166: 1338–44.

Methods

Study of inter-rater reliability and validity of a 10-level scale initially with five investigators (two physicians, two nurses and a pharmacist), then a nurse educator and 27 bedside nurses trained in the scale. Patients were from the medical and surgical ICUs and included ventilated and non-ventilated and sedated and unsedated subjects.

Findings

There was a high correlation between the Richmond Agitation-Sedation Scale (RASS) and other commonly used sedation scores (i.e. Ramsay Sedation Score and Sedation Agitation Scale). Staff described RASS as logical, easy to administer and recall.

Significance

Sedation scores are important tools to consistently set and titrate sedative drugs. The RASS has been found to be a useful tool both at the bedside and in research studies. It is unclear which sedation scale is the best to use, although the RASS appears to be increasingly widespread.

Williams TA, Martin S, Leslie G, et al. Duration of mechanical ventilation in an adult intensive care unit after introduction of sedation and pain scales. American Journal of Critical Care. 2008; 17: 349–56.

Methods

Before-and-after study with 6 months of data collection to evaluate the introduction of the RASS in a general ICU in Australia. Involved 769 patients who received mechanical ventilation for at least 6 hours.

Findings

There was no overall difference in the duration of mechanical ventilation and it increased in those ventilated for longer than 96 hours. Length of ICU stay was similar.

Significance

Ongoing studies are needed to evaluate the effects of various approaches to sedation on a range of meaningful patient outcomes. A major complexity is the interplay of sedation and ventilation that cannot be independently considered. A randomised trial of 336 mechanically ventilated patients in four ICUs evaluated a 'wake-up and breathe' protocol, which paired daily spontaneous awakening trials with daily spontaneous breathing trials. They found a reduced ICU and hospital length of stay, as well as a reduced risk of death (Girard TD, Kress JP, Fuchs BD, et al. Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care (Awakening and Breathing Controlled trial): a randomised controlled trial. Lancet. 2008; 371: 126–34). More studies of this kind are needed.

Riker RR, Shehabi Y, Bokesch PM, et al. Dexmedetomidine vs. midazolam for sedation of critically ill patients. JAMA. 2009; 301: 489–99.

Methods

Prospective, double-blind, randomised, multicentre trial in medical and surgical ICU patients in five countries. Enrolled patients were expected to require mechanical ventilation for at least 24 hours. They received either dexmedetomidine (0.2–1.4 ug/kg/hr) or midazolam (0.02–.1 mg/kg/hr) titrated to a RASS of –2 to +1 from enrolment to either extubation or 30 days. Fentanyl was used for analgesia in both groups. Rescue midazolam could also be used in either group.

Findings

There was no difference in percentage of time within target RASS (the primary outcome measure). More delirium and a longer time to extubation were found with midazolam, but no change in ICU length of stay. More bradycardia requiring treatment in the dexmedetomidine group was also seen.

Significance

This study has been criticised for issues such as failure to disclose the number of patients screened for inclusion, lack of intention-to-treat analysis, lack of an apparent analgesic effect of dexmedetomidine (as comparable doses of fentanyl were needed in each group), failure of the control arm to reflect usual practice (e.g. not ceasing midazolam well in advance of attempting extubation), use of dexmedetomidine doses in excess of the US FDA approved doses and durations. The study adds to our understanding of the safety and efficacy profile of dexmedetomidine, an α_2

agonist that is still finding its place. It also highlights well some of the complexity in performing sedation–analgesia studies in ventilated patients.

Ibrahim MG, Bellomo R, Hart GK, et al. A double-blind placebo-controlled randomised pilot study of nocturnal melatonin in tracheostomised patients. Critical Care and Resuscitation. 2006; 8: 187–91.

Methods

Double-blind, randomised, placebo-controlled pilot study involving 32 tracheostomised patients not receiving continuous sedation. They received either oral melatonin (3 mg) or placebo at 20:00 hours. Pre- and post-dose melatonin levels were measured and the number of hours sleep measured by a bedside nurse.

Findings

Melatonin is well absorbed orally and increases blood levels approximately 1000-fold; however, the increased levels failed to increase observed nocturnal sleep.

Significance

Sleep disturbance in ICU patients is common and we are only starting to understand the range and significance of abnormalities. Melatonin is a naturally occurring hormone produced by the pineal gland and is a key regulator of the sleep–wake cycle. It is inhibited by light and induced by darkness and associated with sleepiness. Low levels of melatonin and loss of circadian rhythms are widespread. There is growing interest in melatonin in ICU patients. This study was one of the first small, randomised trials. Although a negative result, its outcome measure is simplistic and non-objective. A higher quality, although still small study using a higher dose (10 mg) demonstrated an improvement in sleep efficiency but concerns were raised regarding a ‘hangover’ effect with this dose (Bourne RS, Mills GH, Minelli C. Melatonin therapy to improve nocturnal sleep in critically ill patients: encouraging results from a small randomised controlled trial. Critical Care. 2008; 12: 146). A definitive high-quality study is warranted.

Steroids - Other interventions

Bernard GR, Vincent JL, Laterre PF, et al. Recombinant human protein C Worldwide Evaluation in Severe Sepsis (PROWESS) study group. Efficacy and safety of recombinant human activated protein C for severe sepsis. New England Journal of Medicine. 2001; 344: 699–709.

Methods

Multicentre, randomised, double-blind, placebo controlled trial of drotrecogin alfa (activated) in 1690 patients with systemic inflammation and at least one organ failure due to infection, within 24 hours of infection. Recombinant human activated protein C, which has antithrombotic, anti-inflammatory and pro-fibrinolytic properties was infused at 24 mcg/kg/hr for 96 hours.

Findings

There was a 6% absolute reduction in 28-day mortality in the treatment group. There was a non-significant increase in the risk of serious bleeding in the drotrecogin alpha group.

Significance

The use of this therapy in patients with severe sepsis became accepted as conventional for patients where the risks of death from sepsis are judged to outweigh the risks of serious bleeding. The high cost of the treatment led to some institutions forming guidelines for using this therapy, such as a period of assessment of the response to aggressive resuscitation with fluids, vasoactive drugs and antibiotics. Further large, multicentre studies followed.

In the ENHANCE study (Vincent JL, Bernard GR, Beale R, et al. Drotrecogin alfa (activated) treatment in severe sepsis from the global open-label trial ENHANCE. *Critical Care Medicine*. 2005; 33: 2266–77) the same protocol as PROWESS was used, with commencement of the drug within 48 hours of the onset of sepsis. The 28-day mortality was comparable to PROWESS. Patients treated within 24 hours of the onset of organ dysfunction had a significantly lower mortality than those treated after 24 hours (4% absolute improvement). Of concern was an increased incidence in serious bleeding complications.

The ADDRESS study (Abraham E, Laterre PF, Garg R, et al. Drotrecogin alfa (activated) for adults with severe sepsis and a low risk of death. *New England Journal of Medicine*. 2005; 353: 1332–41) evaluated the drug in patients with severe sepsis but low risk of death (APACHE II <25 or single organ failure) and was terminated early as there was no treatment benefit and an increased incidence of serious bleeding.

XPRESS (Levi M, Levy M, Williams MD, et al. Prophylactic heparin in patients with severe sepsis treated with drotrecogin alfa (activated). *American Journal of Respiratory and Critical Care Medicine*. 2007; 176: 483–90) evaluated the safety of concomitant prophylactic heparin and found there was no difference in 28-day mortality between patients who did/did not receive either low-molecular-weight or unfractionated heparin.

Drotrecogin alfa (activated) remains an expensive but potentially beneficial option for treating patients with severe sepsis and a high illness severity where the perceived risk of bleeding is acceptable.

Annane D, Vignon P, Renault A, et al. (CATS Study Group). Norepinephrine plus dobutamine versus epinephrine alone for management of septic shock: a randomised trial. *Lancet* 2007; 370: 676–84.

Methods

Multicentre, prospective, randomised, double-blind trial of adult patients with septic shock in France who have been volume resuscitated and require more than 15 mcg/kg/min of dopamine or any dose of norepinephrine or epinephrine. There were 330 patients who received epinephrine alone or norepinephrine plus dobutamine to maintain a MAP of at least 70.

Findings

There was no significant difference in 28-day mortality or MAP achieved. The epinephrine group had a significantly lower arterial pH on day 1–4 and arterial lactate on day 1.

Significance

This study supported equipoise of both vasoactive drug regimens. Ongoing work is needed to investigate the relative benefits of various combinations in different conditions.

Russell JA, Walley KR, Singer J et al. (VASST Study). Vasopressin versus norepinephrine infusion in patients with septic shock. *New England Journal of Medicine*. 2008; 358: 877–87.

Methods

VASST (Vasopressin And Septic Shock Trial) was a multicentre, randomised, double-blind study of 396 patients with septic shock (lack of response to 500 mL of fluid or >5 mcg/min of noradrenaline), who required low-dose noradrenaline. They received noradrenaline to obtain a MAP 65–75 mmHg then either vasopressin (0.01–0.03 units/min) or extra noradrenaline (5–15 mcg/min).

Findings

No significant difference in 28-day mortality or other adverse events (including cardiac complications and mesenteric ischaemia) was found.

Significance

The study involved patients with a low mortality, without acute coronary syndromes or heart failure. The entry criteria were unusual in that a 500 mL fluid bolus is quite low and many would argue an inadequate fluid challenge before starting vasopressors. For patients needing high doses of pressor the study protocol did not include addition of an inotrope (e.g. dobutamine). It does support that vasopressin may have a safe role if used in patients with vasoplegia, refractory to noradrenaline and without cardiac or mesenteric disease. A post-hoc analysis found a statistically significant mortality and organ dysfunction lowering interaction between vasopressin infusion and those also receiving corticosteroid treatment that warrants further exploration (Russell J, Walley K, Gordon A, et al. Interaction of vasopressin infusion, corticosteroid treatment, and mortality of septic shock. *Critical Care Medicine*. 2009; 37: 811–18).

Rivers E, Nguyen B, Havstad S et al. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *New England Journal of Medicine*. 2001; 345: 1368–77.

Methods

Single-centre, randomised, controlled trial of 263 patients arriving at an urban emergency department with severe sepsis or septic shock. Patients received either 6 hours of goal-directed therapy or standard therapy. Goal-directed therapy in this paper involved aiming for 'normal' values (e.g. CVP 8–12, MAP>65, urine output of at least 0.5 mL/kg/hr, ScvO₂ >70%, Haematocrit >30%). These goals were achieved using an algorithm of fluids, vasopressors, inotropes and packed cell transfusions. The Edwards PreSep™ catheter was employed for the measurement of ScvO₂.

Findings

There was a significant reduction of in-hospital mortality (absolute reduction of 16%) with less severe organ dysfunction (reflected in lower APACHE II scores).

Significance

The use of the term 'goal-directed therapy' should be differentiated from that used in the past with 'supra-normal goals'. It is unclear which aspects of the Rivers study led to the impressive benefits seen. The algorithm used has been criticised, particularly transfusion of packed cells.

It has been said that this may simply reflect the effects of closely monitoring and aggressively resuscitating patients in septic shock. The study also led to renewed interest in the potential utility of ScvO₂ (which may also be measured using blood gas analysis of samples drawn from central lines) as an end-point for resuscitation in septic shock. Large multicentre studies are underway to evaluate early goal-directed therapy versus standard care in patients with severe sepsis (e.g. ARISE in Australasia, PROMISE in the UK, ProCESS in the US).

Tleyjeh IM, Kashour T, Hakim FA, et al. Statins for the prevention and treatment of infections: a systematic review and meta-analysis. *Archives of Internal Medicine*. 2009; 169: 1658–67.

Methods

Systematic review identifying randomised trials and cohort studies examining the association of statin use and risk of infection or outcome of infection.

Findings

Statin use appears beneficial in treating and preventing different infections, but the heterogeneity and publication bias mean that randomised trials are warranted.

Significance

In the ICU population there have been retrospective studies suggesting a benefit of continuing statin therapy in patients admitted with severe sepsis (Gao F, Linhartova L, Johnston AM, et al. Statins and sepsis. *British Journal of Anaesthesia*. 2008; 100: 288–98). Large, randomised studies in critically ill patients are pending (e.g. Australasian STATInS trial of atorvastatin in ICU patients with severe sepsis).

Turgeon AF, Hutton B, Fergusson DA, et al. Meta-analysis: intravenous immunoglobulin in critically ill adult patients with sepsis. *Annals of Internal Medicine*. 2007; 146: 193–203.

Methods

Meta-analysis of 20 controlled trials evaluating polyclonal intravenous immunoglobulin (IVIG) in critically ill patients with sepsis.

Findings

A reduced mortality with IVIG was found and was most pronounced in patients with severe sepsis or septic shock, and with higher and repeated doses. There was no difference in ICU length of stay or duration of mechanical ventilation.

Significance

A large study is needed to confirm these findings and define the most effective dose and type of preparation of immunoglobulin. Benefits may be specifically seen in uncommon, life-threatening conditions such as staphylococcal and streptococcal toxic shock syndromes. Infection in immunosuppressed patients warrants further specific consideration.

Dellinger RP, Carlet JM, Masur H, et al. Surviving Sepsis Campaign guidelines for management of severe sepsis and septic shock. *Critical Care Medicine*. 2004; 32: 858–73.

Methods

Evidence-based expert consensus recommendations.

Findings

Various aspects of acute sepsis management are reviewed with the intention of improving outcomes for critically ill septic patients.

Significance

Some of the conclusions reached have been hotly debated and reflect persisting controversy regarding issues in sepsis management (e.g. role of steroids). The reference list is impressive, covering many of the most quoted papers in the intensive care literature.

The guidelines were revised in 2008 (Surviving Sepsis Campaign: international guidelines for management of severe sepsis and septic shock: 2008. *Critical Care Medicine*. 2008; 36: 296–327. Erratum in: *Critical Care Medicine*. 2008; 36: 1394–6).

Major recommendations from this document form the basis of sepsis bundles that have become widely adopted in some countries, while in others disagreement with the various aspects recommended has led to a more individualised patient approach encompassing various aspects of the strategies proposed.

Hickson M, D’Souza AL, Muthu N, et al. Use of probiotic *Lactobacillus* preparation to prevent diarrhoea associated with antibiotics: randomised double blind placebo controlled trial. *BMJ*. 2007; 335: 80–5.

Methods

Randomised, double-blind placebo controlled study involving 135 patients prescribed antibiotics for respiratory infections or as perioperative prophylaxis for surgery. The endpoint was whether a probiotic drink containing *Lactobacillus* (including *L. casei*, *bulgaricus* and *thermophilus*) can prevent diarrhoea, including diarrhoea by *Clostridium difficile*.

Findings

The probiotic drink was associated with a 75% reduction in risk of antibiotic-associated diarrhoea including from *C. difficile*.

Significance

The study did not include critically ill patients, but the lesson may be of enormous relevance if adequately powered studies can be performed. Probiotics are a topic of great interest, as in addition to the benefits seen in this trial, there is a suggestion they may reduce carriage of vancomycin-resistant enterococci (VRE) and other positive immune-modulating effects. The optimal preparation (e.g. live vs freeze-dried preparations; most appropriate bacterial species) and the safety in an immunosuppressed population remain to be seen. In fact, a study in ICU patients with pancreatitis found no reduction in infectious complications and an increased mortality in the probiotic group with an increased incidence of bowel ischaemia (Besselink MG, van Santvoort HC, Buskens E, et al. Probiotic prophylaxis in predicted severe acute pancreatitis: a randomised, double-blind, placebo-controlled trial. *Lancet*. 2008; 371: 651–9).

Hochreiter M, Kohler T, Schweiger AM, et al. Procalcitonin to guide duration of antibiotic therapy in intensive care patients: a randomized prospective controlled trial. *Critical Care*. 2009; 13: R83.

Methods

Prospective, randomised, single-centre study of 110 surgical ICU patients who received antibiotic therapy after confirmed or suspected infections who either had therapy guided by procalcitonin or a standard empirical duration.

Findings

The duration of antibiotics was significantly reduced in the procalcitonin-guided group without adverse effects on clinical outcome.

Significance

This is one of many such studies that are part of the procalcitonin story. Procalcitonin offers the ‘holy grail’ of being able to differentiate bacterial infection from viral and non-infective inflammatory states. Differing patient populations, varying testing kits and the risks of adverse outcomes in patients with false negative tests make this an ongoing area needing further research.

Steroids - Nosocomial infections

Darouiche RO, Raad II, Heard SO, et al. A comparison of two antimicrobial-impregnated central venous catheters. Catheter Study Group. New England Journal of Medicine. 1999; 340: 1–8.

Methods

Prospective, randomised, clinical multicentre trial in patients perceived to require a central venous line for at least 3 days. Patients received a polyurethane, triple-lumen catheter impregnated with either minocycline and rifampicin (luminal and external surface) or chlorhexidine and silver sulfadiazine (external surface only).

Findings

Some 865 catheters were inserted and a significant reduction in the rates of colonisation and catheter-related bloodstream infections was found with the antibiotic-impregnated group.

Significance

Chlorhexidine and silver sulfadiazine catheters have been shown to be superior to standard lines (Veenstra DL, Saint S, Saha S, et al. Efficacy of antiseptic-impregnated central venous catheters in preventing catheter-related bloodstream infections: a meta-analysis. JAMA: 281: 261–7). Antibiotic-coated lines offer an additional benefit, but the extra cost needs to be factored into the decision to insert these lines. Patients expected to have short requirements for central access are unlikely to benefit significantly from the more expensive lines.

A range of strategies have been investigated for the prevention of catheter-related infections. A meta-analysis has favoured 75% alcoholic/1% chlorhexidine over povidone iodine for skin preparation for vascular catheter insertion (Chaiyakunapruk N, Veenstra DL, Lipsky BA, Saint S. Annals of Internal Medicine. 2002; 136: 792–801). Femoral lines have the highest, and subclavian lines the lowest, rates of infection routine changing of lines does not reduce the incidence of infection and increases the risk of mechanical complications with new line insertion. Changing lines over a guide wire, in the setting of suspected catheter-infection, is associated with increased colonisation but not increased bloodstream infections (Lane RK, Matthay MA. Central line infections. Current Opinions in Critical Care. 2002; 8: 441–8).

Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in ICU. New England Journal of Medicine. 2006; 355: 2725–32.

Methods

Prospective, observational study of rates of catheter-related bloodstream infection before, during and up to 18 months after introduction of an evidence-based intervention regarding central venous catheter management. There were 103 ICUs which contributed data on 375,757 catheter-days.

Findings

The mean rate of catheter-related bloodstream infection was 7.7 per 1000 catheter-days at baseline which reduced to 1.4 at 16–18 months.

Significance

This study demonstrated that improvements could be made with the application of evidence-based principles. Building on this, the more recent focus has been on introducing bundles for reducing central line-associated bloodstream infections (CLABs) that have shown to reduce infections significantly (Koll BS, Straub TA, Jalon HS, et al. The CLABs collaborative: a region wide effort to improve the quality of care in hospitals. Joint Commission Journal on Quality and Patient Safety. 2008; 34: 713–23; Galpern D, Guerrero A, Tu A, et al. Effectiveness of a central line bundle campaign on line-associated infections in the intensive care. Surgery. 2008; 144: 492–5).

de Jonge E, Schultz MJ, Spanjaard L, et al. Effects of selective decontamination of digestive tract on mortality and acquisition of resistant bacteria in intensive care: a randomised controlled trial. Lancet. 2003; 362: 1011–16.

Methods

Randomised, controlled, unblinded trial of 934 patients in two ICUs (medical and surgical) at a single centre, who received oral and enteral polymyxin E, tobramycin and amphotericin B, combined with an initial 4 days of intravenous cefotaxime (selective decontamination of the digestive tract – SDD) or standard treatment.

Findings

There was a significant reduction in ICU and hospital mortality in the SDD group. They found no significant differences in the rate of colonisation with multi-resistant organisms.

Significance

There was a low prevalence of vancomycin-resistant enterococcus (VRE) and no patients were colonised with methicillin-resistant *Staphylococcus aureus*. This was one of the largest studies evaluating SDD. Despite a number of meta-analyses favouring SDD there were still fears that this approach will prove harmful in terms of promoting selection of multi-resistant organisms. A large, multicentre, randomised controlled study is needed to answer the question. The underlying premises are not unreasonable and conventional infection control approaches in ICU are failing to control the threat of multi-resistant organisms.

de Smet AM, Kluytmans JA, Cooper BS, et al. Decontamination of the digestive tract and oropharynx in ICU patients. New England Journal of Medicine. 2009; 360: 20–31.

Methods

Cross-over study of SDD and SOD (selective oropharyngeal decontamination) using cluster randomisation in 13 ICUs in the Netherlands, involving 5939 patients with expected intubation duration of at least 48 hours or ICU length of stay greater than 72 hours. They received 4 days of intravenous cefotaxime and topical tobramycin, colistin and amphotericin B in the oropharynx and stomach. SOD consisted of oropharyngeal antibiotics alone. Monthly point-prevalence studies analysed antibiotic resistance.

Findings

In a population with 28-day mortality of 27.5% the mortality was reduced by 3.5% with SDD and 2.9% with SOD. There was no emergence of antibiotic-resistant pathogens or increased rates of detection of *C. difficile*.

Significance

This is the largest study to date, originating from the Netherlands, the home of SDD. Unfortunately there was no long-term monitoring of the effects on microbial flora. There was a similar benefit of SOD, and the avoidance of systemic and lower dose of gut antibiotics is attractive in terms of the potential expected negative effects on antibiotic resistance patterns. Oropharyngeal decontamination appears to be a more widely accepted strategy, with chlorhexidine the most commonly studied agent and it has been suggested that this should be included in revised ventilator bundles (Wip C, Napolitano L. Bundles to prevent ventilator-associated pneumonia: how valuable are they? Current Opinion in Infectious Diseases. 2009; 22: 159–66).

Steroids - Antibiotic issues

Kumar A, Roberts D, Wood KE, et al. Duration of hypotension before initiation of effective antimicrobial therapy is the critical determinant of survival in human septic shock. Critical Care Medicine 2006; 34: 1589–96.

Methods

Retrospective cohort study of 2731 adult patients with septic shock treated in 14 ICUs. The aim was to determine the influence of the timing and selection of antibiotics on survival to hospital discharge.

Findings

Administration of an antimicrobial effective for isolated or suspected pathogens within the first hour of documented hypotension was associated with a survival rate of 79.9%. Each hour of delay in antimicrobial administration over the ensuing 6 hours was associated with an average decrease in survival of 7.6%. In a multivariate analysis, time to initiation of effective antimicrobial therapy was the single strongest predictor of outcome.

Significance

This paper highlighted the importance of early antibiotic therapy in septic shock and the 'golden hour' of sepsis. The same principal author recently completed a larger study involving 5715 patients with septic shock from three countries. Inappropriate initial antibiotics were administered in about 20% of patients, with a five-fold reduction in survival. The new important message was 'start broad then de-escalate' (Kumar A, Ellis P, Arabi Y, et al. (Cooperative Antimicrobial Therapy of Septic Shock Database research Group). Initiation of inappropriate antimicrobial therapy results in a fivefold reduction of survival in human septic shock. Chest. 2009; 136:1237–48).

Ho KM, Lipman J, Dobb G, Webb SA. The use of prophylactic fluconazole in immunocompetent high-risk surgical patients: a meta-analysis. Critical Care. 2005; 9: R710–17.

Methods

Meta-analysis of seven randomised studies involving 814 patients on intravenous fluconazole (100–800 mg/day) used prophylactically to prevent fungal infections in immunocompetent critically ill or high-risk surgical adults.

Findings

Fluconazole significantly reduced the risk of candidaemia. There was no change in in-hospital mortality, in fluconazole-resistant fungi or side effects.

Significance

Despite this suggestion of benefit, more studies are needed to define the optimal use of these agents in critically ill patients.

Giamarellos-Bourboulis EJ, Pechere EJ, Routsis C, et al. Effect of clarithromycin in patients with sepsis and ventilator-associated pneumonia. Clinical Infectious Diseases. 2008; 46: 1157–64.

Methods

Prospective, randomised, double-blind study of 200 patients with sepsis and VAP intubated and ventilated for at least 48 hours, who received clarithromycin (1 g/day) or placebo in addition to other treatment at the discretion of the treating team.

Findings

There was a significant reduction in the time to resolution of VAP and time to weaning from mechanical ventilation in the clarithromycin group. It also delayed death in those that did not survive.

Significance

The study was only single-centre and the other therapy provided to patients was somewhat unclear. Macrolides, however, may offer non-antibiotic benefits in some conditions such as cystic fibrosis that may have relevance to critically ill septic patients. This warrants further investigation.

Fuster-Lluch O, Geronimo-Pardo M, Peyro-Garcia R, Lizan-Garcia M. Glomerular filtration and albuminuria in critically ill patients. *Anaesthesia and Intensive Care*. 2008; 36: 674–80.

Methods

Prospective, observational study of 89 sequential, heterogeneous, critically ill patients (mean age of 60; 28% with chronic hypertension and 15% with diabetes mellitus) admitted to an ICU. Over a week, urine and blood was collected every morning and analysed for creatinine clearance (hyperfiltration defined as $>120 \text{ mL/min/1.73m}^2$) and proteinuria (expressed as the albumin: creatinine ratio with microalbuminuria defined as $>20\text{--}300 \text{ mg/g}$ and clinical proteinuria as $>300 \text{ mg/g}$).

Findings

There were 18% with glomerular hyperfiltration at admission (none of them was diabetic and only 4/25 had a history of hypertension). This rose to 60% at day 5, then declined. At admission and throughout the study approximately 70% had albuminuria, which was present in most of the patients with hypertension and diabetes. There was no significant association between hyperfiltration and proteinuria.

Significance

Augmented renal clearance may occur for a number of reasons (e.g. vasoactive drugs, hypertension). It is highly relevant, as there are implications for increased excretion of important drugs, such as antibiotics, where levels must be closely monitored and higher than expected dosing regimens may be needed. This may be as important as adjusting dosing in patients with impaired renal function.

Toxicology

Scheinkestel CD, Bailey M, Myles PS, et al. Hyperbaric or normobaric oxygen for acute carbon monoxide poisoning: a randomised controlled clinical trial. *Medical Journal of Australia*. 1999; 170: 203–10.

Methods

Randomised controlled trial involving 191 patients with carbon monoxide poisoning of varying severity. Patients received three once-daily treatments (60 minutes of 100% oxygen at 2.8 atmospheres or a sham treatment) separated by continuous oxygen at 14L/min via non-occlusive facemask. Neuropsychological testing was performed after the initial course of treatment and at 1 month. A further course of 3 days of treatments was instituted if there were abnormalities detected.

Findings

The hyperbaric oxygen group had more delayed neurological sequelae and poor outcomes.

Significance

It was concluded that this therapy was of no benefit and may worsen patients with carbon monoxide poisoning. This prompted a change in practice throughout Australia with a reduction in hyperbaric oxygen (HBO) utilisation for this indication. Importantly, the study excluded pregnant females and children. Criticisms included a poor follow-up rate and very high rate of adverse neuropsychological outcomes compared with other studies, questioning the treatment regimen. A US double-blind randomised trial (Weaver LK, Hopkins RO, Chan KJ, et al. Hyperbaric oxygen for acute carbon monoxide poisoning. *New England Journal of Medicine*. 2002; 347: 1057–67) of 152 patients with symptomatic carbon monoxide poisoning followed. Subjects received either three chamber sessions within 24 hours or 1 normobaric oxygen treatment plus two sessions of exposure to normobaric room air. Regular neuropsychological tests were performed for 12 months. There was a reduced risk of adverse cognitive sequelae at 6 weeks and 12 months in the hyperbaric oxygen group. The American College of Emergency Physicians has concluded that although HBO is a therapeutic option for poisoned patients its use cannot be mandated because the evidence is conflicting and no clinical variables, including CO levels, identify the subgroup of poisoned patients most likely to experience benefit, if one exists (Wolf S, Lavonas M, Sloan E, Jagoda M. Clinical policy: Critical issues in the management of adult patients presenting to the emergency department with acute carbon monoxide poisoning. *Annals of Emergency Medicine*. 2008; 51: 138–52).

Pond S, Lewis-Driver D, Williams G, Green A, Stevenson N. Gastric emptying in acute overdose: a prospective randomized controlled trial. *Medical Journal of Australia*. 1995; 163: 345–9.

Methods

This Australian randomised study enrolled 876 adult patients who presented to the emergency department after ingesting an overdose of one or more compounds able to be absorbed by activated charcoal. One group received charcoal alone and the other had gastric emptying attempted first with ipecac-induced emesis or gastric lavage.

Findings

There was no difference in the clinical course, length of hospital stay or complications between groups, with the conclusion that charcoal alone is appropriate.

Significance

This study changed the face of overdose management. The role of charcoal remains the subject of ongoing research, including the role of multi-dose activated charcoal for 'gastrointestinal dialysis'.

Isbister GK, O'Leary MA, Schneider JJ, et al. (ASP Investigators). Efficacy of antivenom against the procoagulant effect of Australian brown snake (*Pseudonaja sp.*) venom: in vivo and in vitro studies. *Toxicon*. 2007; 49: 57–67.

Methods

In vitro mixtures of brown snake venom and antivenom were used to investigate antivenom binding, neutralisation of prothrombin activity, prevention of venom-mediated clotting and effect on thrombin generation parameters using a thrombinoscope in 27 envenomed patients.

Findings

One vial of antivenom appears to be sufficient to bind and neutralise all venom in patients with severe brown snake envenoming.

Significance

Management of brown snake (and other snake) envenomation creates unique challenges for critical care physicians in Australia. Much debate has been undertaken regarding the amount and type of antivenom required. Some studies have traditionally suggested as much as 10 vials should be administered as an initial dose for severe envenomation. Further research is now looking at the use of fresh frozen plasma (FFP) after antivenom administration. Envenomation with poisonous creatures is a regional problem with highly varying threats. Expert local knowledge is important.

Leskiwa U, Weinberg GL. Lipid resuscitation for local anesthetic toxicity: is it really lifesaving? Current Opinion in Anaesthesiology. 2009; 22: 667–71.

Methods

This article reviews the evolving status of the role of lipid emulsion in LAST (local anaesthetic systemic toxicity). Only laboratory studies and case reports exist as evidence for this therapy. Despite this, it has been embraced by the critical care community, including guidelines produced by the AAGBI (Association of Anaesthetists of Great Britain and Ireland). Current timing and dosing regimens appear to be effective; however, the review suggests under reporting of unsuccessful resuscitations may be biasing results. The guideline is available at www.aagbi.org.

Findings

Present dosing involves up to 2 bolus doses of 20% lipid (1.5 mL/kg). This is followed by an infusion of 0.25 mL/kg/min for 20 minutes or restoration of a stable rhythm.

Significance

There are no randomised controlled trials of this therapy and only minor side effects so far reported. It is, however, no substitute for basic and advanced cardiac life support in the cardiac arrest scenario. Interestingly, some reports exist suggesting benefits from earlier lipid emulsion use in the resuscitation along with adverse interactions with high-dose epinephrine. Lipid may also be a helpful antidote for treating life threatening overdoses with lipid soluble drugs. See www.lipidrescue.squarespace.com.

Trauma - Fluid management

Shaz BH, Dente C, Harris RS, et al. Transfusion management of trauma patients. Anesthesia and Analgesia. 2009; 108: 1760–8.

Methods

This paper reviews the current management of massive transfusion in the trauma patient, reflecting on the introduction of MTP (massive transfusion protocols). With experience from war zones, the earlier introduction of blood components that approximate whole blood is reducing the so-called 'lethal triad' of hypothermia, acidosis and coagulopathy.

Findings

Current practice describes the administration of blood components of plasma, red blood cells and platelets in a 1:1:1 ratio.

Significance

The use of MTPs forms part of what is now called damage control resuscitation in order to reduce ETIC (early trauma induced coagulopathy). It is unclear how best to monitor the effectiveness of this therapy, particularly in the hospital setting where increasingly sophisticated but point-of-care monitors such as thromboelastography (TEG) are available to assist clinicians.

Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. New England Journal of Medicine. 1994; 331: 1105–9.

Methods

Single-centre study of 598 patients with penetrating torso trauma, with assignment to groups by an alternating day assignment system. Fluid was administered from the commencement of pre-hospital care or only after arrival in the operating room.

Findings

Patients in the delayed fluid resuscitation group had a reduced in-hospital mortality, fewer complications (e.g. pneumonia, ARDS, coagulopathy, wound infection, acute renal failure) and a shorter duration of hospitalisation.

Significance

This result has not been replicated. The result cannot be generalised to blunt trauma, or to trauma systems that cannot replicate the rapid delivery of the patient from the scene of the incident to the operating room. There is a significant risk of SIRS and MODS with an increased duration of uncorrected shock. There is a risk of secondary brain injury if there is associated traumatic brain injury.

Despite this, debate has continued and of note the Prehospital Trauma Life Support (PHTLS) and Battlefield Advanced Trauma Life Support (BATLS) protocols support pre-hospital hypotensive resuscitation while the hospital-based Advanced Trauma Life Support (ATLS) protocol continues to recommend normotension.

Cooper DJ, Myles PS, McDermott FT, et al. Prehospital hypertonic saline resuscitation of patients with hypotension and severe traumatic brain injury: a randomized controlled trial. JAMA 2004; 291: 1350–7.

Methods

Randomised, double-blind, controlled trial of 229 patients with traumatic brain injury who were comatose and hypotensive. They received 250 mL 7.5% saline or 250 mL Ringer's lactate solution in addition to conventional intravenous resuscitation protocols.

Findings

No difference in survival or neurological outcome at 6 months.

Significance

This was the first high-quality study using hypertonic saline in this setting. The desirable physiological effects on microcirculatory flow and as a cerebral osmoprotective agent mean that more developments will be forthcoming. Hypertonic saline continues to be evaluated in trauma, including burns patients

Trauma - Burns

Herndon DN, Barrow RE, Rutan RL, et al. A comparison of conservative versus early excision. Therapies in severely burned patients. *Annals of Surgery*. 1989; 209: 547–52.

Methods

Single-centre, randomised study involving 85 patients with burns of greater than 30% total body surface area. Patients were either managed with early excision or topical antimicrobial therapy and skin grafting after spontaneous eschar separation.

Findings

Mortality from burns without inhalation injury was significantly decreased by early excision.

Significance

Early excision and skin cover also reduces the hypermetabolic response to the burn wound, possibly reduces infection, improves cosmesis and has become conventional management. This approach has been facilitated by technological advantages in skin substitutes (e.g. Integra™ – a combination of bovine collagen and shark chondroitin sulphate and Biobrane™ a silicone membrane bonded to a nylon mesh with porcine dermal collagen). Advancements have also been made in the area of antimicrobial topical burn dressings. Nanocrystalline silver preparations are being increasingly utilised in many centres (e.g. Acticoat™). Silver has important antimicrobial properties that are being explored. For example, a recent paper described a reduction in the incidence of VAP with silver-coated endotracheal tubes when compared to standard tubes (Kollef MH, Afessa B, Anzueto A, et al. (NASCENT Investigation Group. Silver-coated endotracheal tubes and incidence of ventilator-associated pneumonia. *JAMA*. 2008; 300: 805–13).

Herndon DN, Hart DW, Wolf SE, et al. Reversal of catabolism by beta-blockade after severe burns. *New England Journal of Medicine*. 2001; 345: 1223–9.

Methods

Randomised trial of 25 children with acute, severe burns of greater than 40% body surface area. Patients in the treatment group received oral propranolol for 2 weeks.

Findings

There was a significant reduction in heart rate, resting energy expenditure and increased muscle–protein balance in the beta-blocker treated group.

Significance

This small study has prompted much interest in the role of beta-adrenoreceptor blockade; however, concerns include prevention of direct anabolic effects of catecholamines and increased mortality in animal studies. Retrospective studies in adults suggest a possible mortality benefit of beta-blockers. There have been a number of studies by investigators seeking to positively manipulate the hypermetabolic response to burns. Growth hormone, anabolic steroids (e.g. oxandrolone) and insulin may all be beneficial. Quality randomised trials in adults are needed.

Navar PD, Saffle JR, Warden GD. Effect of inhalation injury on fluid resuscitation requirements after thermal injury. *American Journal of Surgery*. 1985; 150: 716–20.

Methods

Retrospective study of 171 patients with thermal burns covering at least 25% of total body surface were given fluid resuscitation according to the Parkland formula, with additional fluids to maintain a urine output of 30–50 mL/hr.

Findings

Fifty-one patients had inhalation injuries and this group was found to require an extra 40–50% total fluid requirement.

Significance

This was one of the first papers that clarified that thermal burn patients with inhalation injuries had significantly increased fluid requirements. A later paper found that age over 60 years, burn surface area >40% and inhalation injury were the three factors most associated with death (Ryan CM, Schoenfeld DA, Thorpe WP, et al. Objective estimates of the probability of death from burn injuries. *New England Journal of Medicine*. 1998; 338: 362–6). Controversy continues about the ideal fluid resuscitation strategy to improve burn mortality and excessive fluid volumes may be injurious. The onset of abdominal compartment syndrome is another more recently defined risk factor for an adverse outcome and has been related to excessive fluid administration. A role for novel immune-modulating agents in inhalation injury (e.g. nebulised heparin and drotrecogin alfa) remains to be defined.

Trauma - Spinal injury

Bracken MB, Shepard MJ, Collins WF et al. A randomized, controlled trial of methylprednisolone or naloxone in the treatment of acute spinal-cord injury. Results of the Second National Acute Spinal Cord Injury Study (NASCIS2). *New England Journal of Medicine*. 1990; 322: 1405–11.

Methods

Multicentre, double-blind, placebo controlled study involving 487 patients who received methylprednisolone (30 mg/kg bolus over 15 mins followed by 30 mg/kg/hr for 23 hours) or naloxone (bolus then infusion) or placebo, commenced within 14 hours of injury for 95% of subjects. Motor and sensory functions were assessed at baseline, 6 weeks and 6 months after injury.

Findings

Patients treated with methylprednisolone within 8 hours of injury had significant improvements in sensorimotor function at 6 months for complete and incomplete lesions.

Significance

There was no benefit for naloxone or patients given steroid after 8 hours compared with placebo. The group with the apparent benefit was only a post-hoc subgroup. The methodology of neurological assessment has been the subject of much criticism. Similarly the practical significance of the neurological improvements shown, have been debated. In the subsequent NASCIS3 study, comparison of 24 and 48 hours of methylprednisolone was compared to the neuroprotective agent tirilizad, with treatments commenced less than 8 hours from injury. Tirilizad was found to be equal to 24 hours of steroid but 48 hours of methylprednisolone was superior, although at the cost of increased episodes of severe sepsis. The role of steroids in acute spinal cord injury remains controversial and the decision to use steroids is institution/clinician specific

Trauma - Traumatic brain injury

Traumatic brain injury

Brain Injury Foundation Guidelines. Management and prognosis of severe traumatic brain injury.

www.braintrauma.org/coma-guidelines

Methods

Evidence-based consensus guidelines from experts, to give physicians and trauma centres, some protocols that may improve outcomes.

Findings

Covers issues such as classification, resuscitation, management of raised intracranial pressure, seizure prophylaxis and prognostication.

Significance

The initial document was created in 1995 and the most recently update was in 2007. A key change from the first document made in 2003 was a lowering of the target cerebral perfusion pressure (CPP) from 70 to 60. Aiming for higher CPP targets may be associated with a higher incidence of ARDS. There are also guidelines for prehospital and surgical management; paediatric injury and prognostication of severe traumatic brain injury.

Clifton GL, Miller ER, Choi SC et al. Lack of effect of induction of hypothermia after acute brain injury. New England Journal of Medicine. 2001; 344: 556–63.

Methods

National Acute Brain Injury randomised multicentre study of 392 patients with severe closed head injury (GCS 3–8 after resuscitation) comparing moderate hypothermia (33°C via surface cooling within 6 hours and maintained for 48 hours) versus normothermia.

Findings

No difference in mortality or functional outcome at 6 months was found. Intracranial pressures were found to be lower in the hypothermia group.

Significance

A number of such studies have tested systemic hypothermia as a neuroprotectant and have been negative or equivocal, although the potential benefits of immediate rapid cooling remains unknown. A systematic review has subsequently concluded that mild hypothermia is of no benefit to head-injured patients (Sydenham E, Roberts I, Alderson P. Hypothermia for traumatic head injury. Cochrane database Systematic Reviews. 2009; 1: CD001048). A number of other papers have additionally shown that hypothermia is a useful adjunct for management of refractory intracranial hypertension but it remains unknown if this translates into improvements in outcomes.

Roberts I, Yates D, Sandercock P, et al. Effect of intravenous corticosteroids on death within 14 days in 10008 adults with clinically significant head injury (MRC CRASH trial): randomised placebo-controlled trial. Lancet. 2004; 364: 1321–8.

Methods

Multicentre, randomised, double-blind trial of 10,008 patients with head injuries of all severities (entry criteria of GCS ≤14 within 8 hours of injury). Patients received either methylprednisolone (2 g loading dose then 0.4g/hr infusion for 48 hours) or placebo.

Findings

There was an increased risk of death from all causes within 2 weeks in the group who received steroids. The relative increase in death did not differ by injury severity or time since injury.

Significance

The mechanism of harm is unclear and prompted many clinicians to re-examine their approach to prescribing corticosteroids in spinal injury, although some units continue to believe a group of neurotrauma patients may benefit.

Cooper D.J., Rosenfeld J.V., Murray L, et al. (DECRA Trial Investigators and the Australian and New Zealand Intensive Care Society Clinical Trials Group): Decompressive craniectomy in diffuse traumatic brain injury. New England Journal of Medicine. 2011; 364 (16): 1493–502.

Methods

Randomised, international multicentre study of 155 adults with severe diffuse TBI with intracranial hypertension (>20 mmHg for 15 mins), refractory to first-tier therapies, to bifrontotemporoparietal decompressive craniectomy or standard care.

Findings

The decompressed group had statistically significant reductions in ICU length of stay and easier to manage ICP in ICU, but a worse functional outcome (Extended Glasgow Outcome Scale). There was no difference in 6-month mortality.

Significance

The role of decompression remains unclear, but has been called into urgent question as it does not appear to provide the desirable benefits hoped for. Criticisms of this study have included selection bias (one centre contributed a disproportionate number of patients, while recruitment at others may have been slow, with insufficient time for first-tier therapies to work), and that the methods didn't address patients with mass lesions requiring evacuation.

Trauma - Other issues

Spahn DR, Cerny V, Coats TJ, et al. Task Force for Advanced Bleeding Care in Trauma. Critical Care. 2007; 11: R17.

Methods

Evidence-based recommendations.

Findings

Key recommendations pertain to the time elapsed between injury and operation being minimised for patients in need of urgent surgical bleeding control. Patients presenting with haemorrhagic shock and an identified source of bleeding should undergo immediate surgical control bleeding unless initial resuscitation measures are successful. Pelvic ring disruptions should be closed and stabilised, followed by appropriate angiographic embolisation or surgical bleeding control, including packing. Patients presenting with haemorrhagic shock and an unidentified source of bleeding should undergo immediate further assessment as appropriate using focused sonography, computed tomography, serum lactate and/or base deficit measurements.

Significance

This is a common problem and outcomes depend on efficient systems and processes for managing patients. These need to be periodically reviewed as new evidence emerges

